End use energy data collection for Alaska buildings

Guidance Document

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Contents

1. Recommendations

The following are intended to properly “Alaskanize” an end use energy data collection effort.

1. Focus on data collection, not modeling, not analysis, not forecasting. Use the end use accounting framework to organize data and to compare calculated bottom-up estimates with aggregate top-down data. Do not conduct forecasting exercises.

2. Direct special effort toward collecting accurate square footage and building shell data *for residential buildings*. (Nonresidential buildings are normally accounted for on a square ft basis, but residential are often not treated this way).

3. Treat the effort as five distinct studies, and use the following key methodologies:

	residential	nonresidential
Railbelt	• phone survey, possible internet survey after phone contact • Can draw samples from utility billing records, stratified by region and consumption level • electricity billing data • gas billing data • delivered heating oil billing data	• floorstock data from assessors • possible phone survey stratified by building type; draw sample from assessor data or utility billing data • on-site walk-through assessments • billing data • possible effort to discern value of service to commercial customers by time and season of use
Southeast	• Same as Railbelt, but separate sampling frame • phone survey, possible internet followup • electricity billing data • gas billing data • delivered heating oil billing data	• Same as Railbelt, but separate sampling frame. Floorstock data likely unavailable for some smaller communities, if so use random sampling from utility records.
Rural North and West	• Integrated collection of residential and nonresidential buildingsdata • Take full advantage of available supplemental data: *PCE (monthly, by cust. class), and ARIS database *Billing data for entire communities (start with AVEC) *One-shot data collection efforts (RuralCAP home visits, ISER/Schwoerer field trip, ISER/NSB assessment, others) • On-site survey visits required for all building characteristics. • Use pilot effort (1 community) to test field data protocol and to ascertain likely range of variation, OR hold back resources in a “sampling reserve” • Stratify by size class (basically Hub and non-Hub) and then use Cluster sampling to reduce cost and to maximize the sampled variation • Assess nonresidential buildings along with residential: Sample at same time, within same clusters. • Key informants likely to be very helpful (city administrator, school district staff) and may span multiple communities • Take advantage of PCE data on overall use and billing data for entire communities to validate/calibrate end-use data.	

4. For Railbelt, attempt to access residential gas and fuel oil billing data in addition to electricity billing data.

5. For the Rural North, treat primary data collection through on-site survey methods as a "validation" exercise to validate existing data.

6. For the Rural North, conduct a pilot test of on-site data collection to try out protocol and to estimate likely range of variation within a community. Use the knowledge to finalize a sampling plan for this region consistent with an overall budget allocation for this study component.

7. For nonresidential buildings in the Railbelt and Southeast, at least some effort should be directed toward ascertaining the economic value of electricity service by time of day and/or season to nonresidential customers. This knowledge could be crucial for future integration of intermittent renewables into the grid and/or for peak load management. Ascertaining value of service should NOT be a priority for residential customers or for the Rural North/West regions.

2. End use framework

The end use framework is primarily an accounting system that keeps track of many small components of energy use. The residential and nonresidential buildings are treated as completely separate sectors. Within each sector, the three primary dimensions of the framework are:

1. Building types
2. Fuel types
3. End uses

See Appendix 1 for the building types and end uses included in typical end use models as employed in 1988. Information technology is an additional distinct end use that should be accounted for today.

Understanding the framework is very important for sound decisionmaking about data collection and is worth the effort that may be required. It is easiest to understand by using examples. Appendix 1 contains a more technical and abstract discussion.

Example 1. Suppose there are 200 residential customers with single-family houses. Of these, 100 have garages and the other 100 use 1 engine block heater each. Each block heater uses 500 kWh per year. All block heaters are electric. Under these assumptions, the use

in	building type	residential single-family
of	fuel type	electricity
for	end use	block heaters

equals: 200 houses x 50% with electric block heaters x 500 kWh = 50,000 kWh

In this example, the 200 houses is a measure of **floorstock**. The 50% is a measure of **electric market share**. The 500kWh per block heater is a measure of **energy use index or EUI**.

In this example the overall **energy intensity or EI** of electricity use for block heaters is 50,000 kWh divided by 200 customers = 250 kWh per customer. This is a statistical quantity. If all the residential electricity EI values for each end use are added up, we would arrive at average electricity use per residential customer.

Example 2. This example is more complicated but gets at the heart of Alaska's energy challenges. This example is residential space heating. There are:

Two building types	single family and mobile home
Two fuels	electricity and natural gas

I have constructed a miniature end use model of this residential end use. The model is shown in the following table for realistic parameter values other than the number of houses. (The mode is available at www.iser.uaa.alaska.edu/iser/people/Colt/Enduse_minimodel.xlsx)

Table 1. End use mini-model

End Use Framework as typically employed

	end use ------------->		heat				
	building type ---------->		single family		mobile home		Total
		typical units					
FLOORSTOCK		# of houses	100		100		200
	fuel type		elec	gas	elec	gas	
SHARE		fraction	0.1	0.9	0.1	0.8	
	economic service demand	HDD	14,000	14,000	14,000	14,000	
	building shell efficiency	baseboard btu/HDD/house	6,400	6,400	6,000	6,000	
	energy service demand	baseboard mmbtu/house	90	90	84	84	
	furnace efficiency	%	1.00	0.80	1.00	0.80	
EUI	energy end use demand per house	metered mcf/house		109		102	
		or metered kWh/house	26,253		24,612		
UTILIZATION	scale factor for short-run behavior change	scale factor	1.0	1.0	1.0	1.0	
SALES	energy sales	MWh elec	263		246		509
		mcf gas		9,786		8,155	17,942
EI	Electricity energy intensity for heating	kWh per average house	2,625		2,461		

The yellow rows show the standard elements of the end-use framework: Floorstock, market share, energy use index, and "utilization." The utilization parameter is shown for completeness. Utilization is a way to incorporate short-term behavioral change into modeling and forecasting, but we can ignore it for this discussion.

The SALES row is typically the “bottom line” of the end use models used by utilities. Electricity sales are the arithmetic product of the four yellow rows:

SALES = FLOORSTOCK x SHARE x EUI x UTILIZATION

This “equation” is an accounting identity. The benefit of the end use approach to understanding energy use is that is forces us to consider each of these factors and keeps track of how important each one can be.

In the mini-model, I have expanded the chain of reasoning to explicitly show the determinants of the EUI. The economic service demand is for a warm house. Given the climate (measured by HDD), the demand for energy services (measured by btu of heat delivered into the heated space) is determined by the heat-loss efficiency of the building shell. The demand for end-use energy itself (measured as mcf or kWh) is further determined by the furnace efficiency. Of course there are other ways to decompose the amount of fuel purchased for heating into components. I have chosen these components because they lead directly to data collection needs related to heating.

Above, the cells highlighted in light blue are data requirements. The number of houses can be estimated from residential customer counts and the HDD data are readily available. It is the market shares, the building shell characteristics, and the furnace characteristics that require primary data collection.

At the bottom of the table above I also compute the energy intensity (EI) values for electricity used for space heat as would typically be computed in an end use model. Again, these EI values are statistical average quantities.

Extension to progress and tracking metrics. In my mini-model I demonstrate how the framework can be easily extended to compute primary energy use and GHG emissions associated with the end use of residential heating. Progress can then be tracked either in absolute terms or as a change in intensity – energy use per square foot. The following table shows the importance of somehow measuring house area to allow for the tracking of energy intensity.

Table 2. Extension of end use results

		single family		mobile home		
Extension to primary energy and GHG emissions		elec	gas	elec	gas	Total
T&D efficiency	%	0.95	0.95	0.95	0.95	
generation efficiency	%	0.55	1.00	0.55	1.00	
primary energy converted	mcf gas	1,665	10,301	1,561	8,585	22,112
GHG emissions	metric tons CO2	91	563	85	470	1,210

		single family	mobile home	Total
Possible tracking metrics				
Average size of houses	ft2/house	2,000	800	
Total ft2 of floorstock	ft2	200,000	80,000	280,000
EI for electricity for heat	kWh/ft2	1.31	3.08	1.82
EI for primary gas for heat	mcf burned per ft2			0.0790
EI for GHG emissions for heat	kg CO2 per ft2			4.32

3. Railbelt end use situation

For electricity, the 1989 ISER Railbelt end use study found the following distribution of electricity SALES circa 1987.

[continued on next page]

Figure 1.

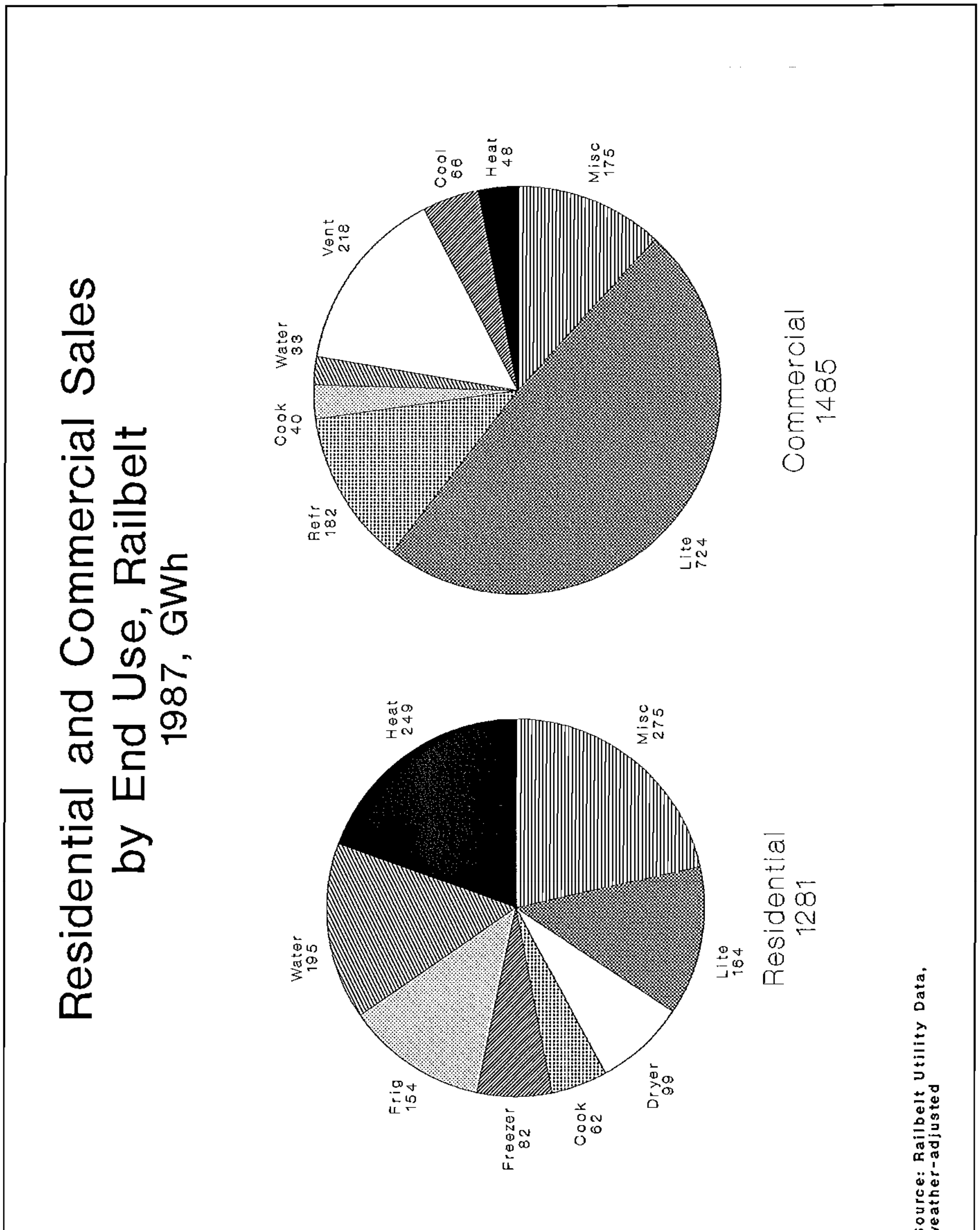

Figure 1.2: 1987 Railbelt Residential and Commercial Electric Sales by End Use

1 - 4

4. Priorities for end use data collection

With the end use framework laid out in simple form, I briefly discuss the possible goals of additional data collection.

Long-term goals for Alaska

Possible long-term goals for the people of Alaska, as embodied by the current EEBG project and the EECWG include the following. (They are numbered mostly for ease of reference in a discussion, and not because I think this is the right priority order).

1. Reduce total fossil fuel use over time
2. Reduce total GHG emissions over time
3. Reduce total diesel and heating oil use over time (perhaps by substituting propane or natural gas)
4. Reduce fossil fuel energy intensity – total use *per square foot*.
5. Reduce GHG emissions intensity – CO2 *per square foot*
6. Others ??

Short-term goals of end use data collection

Immediate *potential* goals of end use energy data collection include the following, again numbered only for ease of reference.

1. Account for current total energy consumption in buildings by end use
2. Provide a baseline against which trends can be accurately measured
3. Track changes over time in consumption of fuels and GHG emissions
4. Track changes over time in energy and GHG intensities.
5. Provide an empirical basis for private sector initiatives; suggest market opportunities
6. Determine possible cost-effective programs and policies and how much they might accomplish
7. Track the success of those programs and policies that are implemented
8. Provide an objective basis for evaluating project proposals made by other entities
9. Track changes in energy intensity of the economy (energy/GDP)
10. Determine interaction effects and "extenalities" associated with some interventions; avoid double-counting savings. (example: reducing the lighting load served by electricity can increase the heat load served by gas).
11. Forecasting
12. Others ??

Data collection priorities in relation to goals

I now briefly consider how the above goals can be used to establish data collection priorities consistent with resource constraints. Ultimately, it is up to the EECWG and other decision-makers to clarify their goals and determine total available resources.

Here I offer my own reasoning and opinions consistent with the recommendations made above in section 1.

First, if the goal is to reduce overall energy use, it is imperative that we better understand space heating. Alaska has no systematic or comprehensive assessment of its housing or building stock, nor do we have any systematic data on furnaces, stoves, and nonresidential heating equipment. Residential space heating is particularly important to residents of northern and western rural Alaska. Placing a priority on understanding space heating across all fuel types probably means sacrificing some detail or precision in estimating *electricity* consumption by end use.

Second, if the goal of tracking energy intensities (use per square foot) is important, then residential data collection should include special attention to gathering square footage data. This attention can take several forms, which may include additional probing in phone or internet surveys; direct measurements when on-site methods are used; and cross-checking property appraisal records when these are available (as they are in Anchorage on the Muni Web site).

Third, if the goal is to effect change in statewide totals, then data collection resources should be allocated roughly in proportion to overall energy use. Overall use can be proxied by population and then adjusted. The statewide breakdown of population is shown below (Table 3) and population is tentatively allocated into the three regions that I am calling **Railbelt**, **Southeast**, and **Rural North/West**. More than 75% of the population is in the Railbelt. Only 13% is in the Rural North/West, even though I have allocated Kodiak and the Valdez-Cordova census area to this region. Adjustments to these fractions for determining allocation of resources would logically include:

- Increase the importance of the Rural North/West region because it is colder and because energy costs more
- Increase the importance of the Railbelt and Southeast because they have relatively more nonresidential floorstock
- Increase the importance of both Rural and Southeast because each is a small region and needs to be "oversampled" in order to generate reliable data for that region alone.
- Increase the data collection resources for Rural North/West because onsite data collection is required and is more expensive
- Other factors??

Taking these factors into account suggests that a split of 80% for Railbelt plus Southeast and 20% for Rural North/West might be appropriate. The EECWG should carefully consider this allocation and should craft its RFP to indicate the allocation to proposers.

Table 3. Alaska population by labor market region and census area

Railbelt	77%
Rural North/West	13%
Southeast	10%

		Studyarea	Area Name	Est. Pop 2009	Census Pop 2000
			Alaska	692,314	626,931
54%			Anchorage / Mat-Su Region	374,902	319,605
	42.0%	Railbelt	Anchorage, Municipality of	290,588	260,283
	12.2%	Railbelt	Matanuska-Susitna Borough	84,314	59,322
11%			Gulf Coast Region	76,686	73,799
	7.7%	Railbelt	Kenai Peninsula Borough	53,578	49,691
	2.0%	Rural North	Kodiak Island Borough	13,860	13,913
	1.3%	Rural North	Valdez-Cordova Census Area	9,248	10,195
16%			Interior Region	108,463	97,417
	0.3%	Railbelt	Denali Borough	1,838	1,893
	13.5%	Railbelt	Fairbanks North Star Borough	93,779	82,840
	1.0%	Railbelt	Southeast Fairbanks Census Area	7,243	6,174
	0.8%	Rural North	Yukon Koyukuk Census Area	5,603	6,510
3%			Northern Region	23,664	23,789
	1.4%	Rural North	Nome Census Area	9,500	9,196
	1.0%	Rural North	North Slope Borough	6,798	7,385
	1.1%	Rural North	Northwest Arctic Borough	7,366	7,208
10%			Southeast Region	69,338	73,082
	0.3%	Southeast	Haines Borough	2,286	2,392
	4.4%	Southeast	Juneau City and Borough	30,661	30,711
	1.9%	Southeast	Ketchikan Gateway Borough /2	12,984	14,059
	0.8%	Southeast	Prince of Wales- Outer KTN	5,392	6,157
	1.2%	Southeast	Sitka City and Borough	8,627	8,835
	0.4%	Southeast	Skagway-Hoonah-Angoon C.A.	2,908	3,436
	0.8%	Southeast	Wrangell-Petersburg Census Area	5,852	6,684
	0.1%	Southeast	Yakutat City and Borough	628	808
6%			Southwest Region	39,261	39,239
	0.4%	Rural North	Aleutians East Borough	2,778	2,697
	0.7%	Rural North	Aleutians West Census Area	4,549	5,465
	2.5%	Rural North	Bethel Census Area	16,997	16,046
	0.1%	Rural North	Bristol Bay Borough	967	1,258
	0.7%	Rural North	Dillingham Census Area	4,729	4,922
	0.2%	Rural North	Lake and Peninsula Borough	1,547	1,823
	1.1%	Rural North	Wade Hampton Census Area	7,694	7,028

(source: DOLWD)

Fourth, if the goal is to integrate renewable and alternative energy sources into the statewide mix, it is probably important to include in the nonresidential survey efforts some questions about the value of electricity service for various uses and by time and season of use. Conventional end use models are focused on annual energy use, or perhaps on one-time peak demand, so a focus during data collection on **value** and on **when** that value is high would probably be a departure from standard end use modeling methods. Knowing something about value in relation to time of use could be helpful for future integrated resource planning exercises.

5. Sampling strategies

Surveys

I have recommended that there be three study regions: Railbelt, Southeast, and Rural North/West. For the Railbelt and for Southeast, telephone and/or internet survey methods can be employed. On-site assessments will likely be required for the nonresidential sector. (However, accurate floorstock data should generally be available from property appraisal computer systems.) For the Rural North/West region, on-site data collection will be required for both residential and nonresidential sectors.

I recommend cluster sampling – meaning a focus on a small number of communities witha high sampling fraction within each -- of the Rural North/West region for two reasons. First, on-site work in this region is so expensive that it practically demands a concentration of resources. As one statistician put it, “It is clearly economically essential to concentrate large-scale surveys within a relatively small number of districts” (Stuart 1984, p. 71). This is the standard rationale for sampling within clusters. However, there is a second reason for cluster sampling in the context of rural energy use. It is likely that the variation in use among individual buildings within a rural community is greater than the variation in average use between communities. For example, we know that most villages contain a wide “mix” of houses, buildings, occupants, and energy-using behavior. By collecting data from a high proportion of all buildings in one community, we can be relatively confident that we are capturing this variation. In contrast to this approach, simple random sampling of the same number of total buildings in several communities could result in missing out on the full variation in use per building.

“Supplemental” information

There are several good sources of supplemental information that can be used to complement survey methods.

In the Railbelt, we can take advantage of the relatively small number of utilities to gather actual billing data at low cost. In the 1987 ISER study, for example, consent was sought from residential survey customers by asking them for their gas and electric account numbers. Nonresidential customers signed release forms included in a one-page mail survey.

Additional Railbelt data includes the Wattbuster program results covering 32 nonresidential buildings (although this “sample” is not random and 87% of the square feet are office space).

In Southeast, more effort will be required to acquire heating fuel billing data, but the effort should be attempted if it is agreed that understanding overall energy use is the goal.

For the Rural North/West region, there are several excellent sources of end use data. These include, but are probably not limited to, the following:

- PCE data – monthly sales to each community by customer class
- RuralCAP EnergyWise home visits – more than 1,000 on-site assessments of basic energy characteristics, including square feet, coded by ISER into a relatively clean dataset
- Comprehensive on-site data collection in four Norton Sound communities by Tobias Schwoerer (part of the AHFC/ISER project to develop a generic small community end use model covering all end uses). The Schwoerer dataset includes 54 households, 19 public buildings other than schools, and several school buildings.
- On-site monitoring and assessment data compiled by Dennis Meiners for several villages in the Yukon-Kuskokwim delta region.

Because of the availability of these data sources, I recommend that these data be considered a primary or initial source of end use information and that on-site data collection in the Rural North/West region be used to validate these existing data and fill gaps. Substantial office work will be required to extract and “conform” the available data listed above, and there may be confidentiality issues to be adressed. However, the cost of pooling and using these data is far lower than the cost of duplicating the collection efforts.

Adaptive or Bayesian approach

Bayesian statistical methods rely on the use of so-called “prior” estimates that are revised in a well-specified way as additional data are gathered. The new information from gathered data is sometimes used to determine where and how much to collect additional data (Little, Goldstein & Jonathan 2003; Goldstein 1998).

A full-blown Bayesian approach is probably not worth the extra effort. However, there are two ways in which the basic idea or spirit of the Bayesian approach could be utilized in the Rural North/West region to maximize the net benefits of expensive fieldwork. One way would be to conduct a pilot survey in one community. The purpose of the pilot would be to pre-test the survey instruments, but also (and this is the Bayesian part) to ascertain the likely ranges of variation in energy use for various end uses. The likely ranges of variation are necessary to determine the required sample sizes needed to achieve any given level of sampling error for quantities other than proportions. To illustrate this concept with an extreme example, suppose that the pilot study of almost every house in small community A finds that the standard deviation of heating fuel consumption per square foot is very low. Knowing this, a relatively small and simple sample could be considered that focused on accurate square footage data.

The second way in which the Bayesian “adaptive” approach could be used would be to proceed with a full sampling plan, but also to hold back a “sampling reserve” within the budget for the additional data collection deemed to have the highest benefit/cost ratio after looking at the initial data.

Only one of these approaches should be used. Perhaps the RFP can simply encourage proposers to suggest methods for adaptive on-site sampling strategies and can acknowledge that the on-site rural sampling plan need not be fully specified in advance of initial data collection.

6. Concluding discussion

The 1989 ISER Railbelt end use study demonstrated that the combination of a residential telephone survey, on-site nonresidential building assessments, floorstock data from property appraisal systems, and collection of billing data was sufficient to “feed” relatively complex end use forecasting models. However, these models were used for a one-time forecast of electricity sales in the Railbelt.

In contrast, the current effort is to support an ongoing assessment of overall energy use in buildings – not just electricity – for the entire state. This expanded scope will require that the “tried-and-true” methods that worked in 1989 be adjusted and amended. The key changes, as outlined in the section 1 recommendations above, are:

- Focus more data collection effort on space heating using all fuel types even though that means sacrificing some precision for other electricity end uses.
- Consider modeling residential space heating on a per square foot basis rather than a per household basis.
- Consider asking nonresidential customers in Railbelt and Southeast about perceived value of service and how that value varies over time.
- Allocate roughly 20% of data collection resources to Rural North/West, even though this region contains only 13% of statewide population.
- Collect all survey data from the Rural North/West region using on-site methods
- Rely heavily on existing data about Rural North/West energy use
- Do not use up resources preparing forecasts or running complicated end use models. Instead, employ the end use framework to organize data collection, compilation, and basic statistical analysis.

Annotated list of references and documents reviewed

Alaska studies

Chaney, R.; Colt, S.; Johnson, R.; Wies, R.; White, G. 2004. Galena electric power: a situational analysis. Anchorage: ISER. Prepared for National Energy Technology Laboratory. Award number DE-FC26-01NT41248.

Colt, S., Foster, K; Kruse, J. 1989. Forecast of electricity demand in the Alaska Railbelt region: 1988-2010. Anchorage: ISER. Prepared for Alaska Power Authority.

http://www.iser.uaa.alaska.edu/Publications/Forecast_ElectricityDemandAKRailbelt_1988-2010.pdf

Comprehensive end-use study and forecast for Railbelt region. Residential phone survey (n=700), commercial mail survey (n=500), on-site walk-throughs (n=110). Report contains survey instruments.

Colt, S., Mitchell, A.; Schutte, R. 1992. North Slope Borough energy assessment. Prepared for Arctic Slope Regional Corporation and North Slope Borough.

Utilizes actual data on total fuel deliveries to remote villages in North Slope Borough and electric meter data to calibrate simplified end use models of electricity, space heat, and other uses.

Scwhoerer, T.; Fay, G. 2010. Economic Feasibility of North Slope Propane Production and Distribution to Select Alaska Communities.

report: http://www.iser.uaa.alaska.edu/Publications/Schwoerer_ay2010propane_phase2final.pdf

model: http://www.iser.uaa.alaska.edu/Publications/Schwoerer_Fay2010propane_phase2.xlsx

The model contains distilled “best guesses” of 4 market shares for heating appliances: 1) Monitor stove, 2) furnace/boiler, 3) electric, and 4) wood/other. It also contains distilled best guesses for energy use index (EUI) values for space heating, water heating, and cooking using propane

Colt, S. 1995. Electric load forecast for Haines, Chilkat Valley, and Kake, Alaska. Anchorage: ISER. Prepared for Alaska Division of Energy.

This study used trend analysis and highly simplified end use forecasting but is perhaps noteworthy for attention to so-called "discrete large loads" and how they might affect overall demand.

Colt, S. 1995. Kenai Peninsula natural gas study. Anchorage: ISER. Prepared for Kenai Peninsula Economic Development District. Contact ISER for hard copy.

Short report, considers economics of gas conversions including cost of adding gas transmission and distribution. Concludes that residential and commercial customer density is insufficient in lower Kenai Peninsula to add gas. Also considers extent of gas penetration circa 1995.

Colt, S. 1993. Estimated costs to Alaskans of the proposed 1993 BTU energy tax. Anchorage: ISER. Prepared for Alaska Housing Finance Corporation, Office of Energy Programs.

Shorter memorandum, considered statewide electricity, heating, and domestic hot water usage based mostly on engineering calculations and overall electricity consumption data. Potentially useful as one more "reality check" on aggregated end use consumption.

U.S. Lower 48 documents and Web sites

EPA, Energy Star Program. 2010 Licensed Professional's Guide to the ENERGY STAR ® Label for Commercial Buildings.

This guide contains in particular:
Appendix C. Example Copy of a Statement of Energy Performance. The primary metric of EP is energy intensity (kbtu/ft2) combining electricity and direct fuel use. Electricity is consumption is measured both at the site (kWh purchased) and as primary energy (fuel consumed for generation).

Appendix D. Example Copy of Data Checklist
The data checklist primarily includes building square feet, type, occupancy rate (*not* occupancy factor) billing/metered consumption data

Energy Efficiency Best Practices Project
http://www.eebestpractices.com/index.asp [accessed 8 Dec 2010]

"This study is managed by Pacific Gas and Electric Company under the auspices of the California Public Utility Commission in association with the California Energy Commission, San Diego Gas and Electric, Southern California Edison, and Southern California Gas Company."

“The purpose of this best practices project is to develop and communicate excellent practices nationwide in order to enhance the design, implementation, and evaluation of energy efficiency programs. The project uses a benchmarking methodology to identify best practices for a wide variety of program types.”

Quantum consulting was the prime consulting contractor. The Principal, Mark Rufo, appears to have taken the project with him to Itron. It is hard to tell if the project is still ongoing as of 2010.

Sector reports are the backbone of the project outputs. Example:

Quantum Consulting. 2004. National energy efficiency best practices study. Volume R1 – Residential lighting best practices report
http://www.eebestpractices.com/pdf/BP_R1.PDF

Efficiency VT acheived:
program budget: $1.6 million
of which incentive payments totaled: $655,000
leaving $945,000 as admin costs
Savings: 11,000 MWh/yr = 11 GWh/yr
Program admin cost = $.09 per annual kWh
source: Exh. R1-1 (p. R1 – 12)

Quantum Consulting. 2004. National energy efficiency best practices study. Volume S -- Cross-cutting best practices and project summary.
http://www.eebestpractices.com/pdf/BP_Summary.pdf [8 Dec 2010]

DEER - Database for Energy Efficient Resources
http://www.energy.ca.gov/deer/ [8 Dec 2010, last updated Dec 2008]

DEER is a CA Energy Commission platform and database to support rulemaking and regulations.

The “Data update guide for 2008”:
http://www.deeresources.com/deer0911planning/downloads/DEER2008UPDATE-EnergyAnalysisMethodsChangeSummaryV9.pdf

is instructive about what kinds of measures are considered. For example see p. 13 which references internal gains...it’s pretty engineering-heavy.

Other references

Goldstein, M. 1998. Bayes linear analysis. *Encyclopedia of Statistical Sciences*. 1998 Supplement: 29-34.

Stuart, Alan. 1984. The ideas of sampling. London: Charles Griffin.

Stern, P.; Gardner, G.; et al. 2010. Design Principles for Carbon Emissions Reduction Programs. *Environmental Science and Technology* 44: 4847–4848

Little, J.; Goldstein, M.; Jonathan, P. 2003. Efficient Bayesian sampling inspection for industrial processes based on transformed spatio-temporal data. Unpublished monograph. Contact email: J.D.Little@durham.ac.uk

Appendix 1. Excerpts from 1989 Railbelt End Use Study

(begins on next page)

These excerpts include a more detailed and technical discussion of the typical end use modeling framework, as well as some results from the analysis.

1.3 End Use Forecasting Models

In contrast to aggregate econometric models which treat electricity as a pure commodity such as milk or concert tickets, end use models treat the demand for electric energy as a *derived demand* which depends explicitly on the stock of electric appliances, their inherent efficiency, and the intensity with which they are used. The models used in this study are stock-flow models of the building and appliance capital stocks coupled with behavioral equations which simulate consumer choice in response to changing economic variables. Total sales are approached from the "bottom up" by aggregating over end uses and building types. The entire energy market is modeled. Competition between electricity and other fuels is a central determinant of total electric load.

End Use Model Classifications

Residential

End Uses

HEAT	: Heating
WATR	: Hot Water
FRIG	: Refrigeration
FREZ	: Freezer
COOK	: Cooking
DRY	: Clothes Drying
LITE	: Lighting
MISC[1]	: Miscellaneous

Building Types

SINGL	: Single Family
MULTI	: Multi Family (2+ units)
MOBIL	: Mobile Home

Commercial

End Uses

HEAT	: Heating
COOL	: Space Cooling
VENT	: Ventilation
WATR	: Hot Water
REFR	: Refrigeration / Freezing
COOK	: Cooking
LITE	: Lighting
MISC	: Miscellaneous

Building Types

SMO	: Small Office (<20,000 Ft2)
LGO	: Large Office
RES	: Restaurant
LGR	: Large retail (>20,000 Ft2)
SMR	: Small Retail
GRC	: Grocery
WRH	: Warehouse
CAR	: Auto Service
LDG	: Lodging
MED	: Medical
SCH	: School
COL	: College[2]
ASB	: Assembly
MISC	: Miscellaneous
VCT	: Vacant

[1]Miscellaneous includes (residential) small appliances, headbolt heaters, roof heat tape, waterbed heaters, saunas, and jacuzzis; (commercial) office equipment, vending machines, automobile heater outlets.

[2]College includes UAA but not UAF. UAF is primarily a self-generator.

1.3.1 Basic Concepts

We model end use energy demand using the following terms to represent "stylized facts". These concepts grossly simplify the structure of a complex market. However, they create a consistent framework for analysis which can be populated by available data.

- Floorstock measures the size of the market for energy services. Commercial floorstock is measured in square feet (Ft2) for 15 separate building types. Residential floorstock is measured in housing units of 3 types.

- Market Share is the fraction of the total market for a given end use that is actually served by a given fuel type. In the residential sector, the total market is defined to include all households and the residential market share is equal to the product of the more familiar "saturation rate" and "fuel mode split" terms.[6] Commercial market shares are defined relative to the total market penetration of the end use. Since this penetration is generally 100%,[7] commercial market share is generally analogous to fuel mode split. Not surprisingly, the importance of market share for a given end use/building type combination in determining total sales depends on the end use's importance in building sales and the building type's importance in total sales (see box).

- Energy Use Index (EUI) is a measure of consumption per appliance per year for a given end use and fuel. In the commercial sector we measure EUIs as energy per Ft2 of floorspace. EUI values are fuel-specific and end use-specific. For residences, electric EUI is expressed as kWh per appliance. For lights and miscellaneous appliances, electric EUI is measured on a per-household basis.

- Energy Intensity (EI) is a summary measure of energy consumption of a particular fuel per unit of floorstock. It is defined to be the product of market share and EUI. An overall EI can also be computed as the sum of EIs for all end uses. Overall Intensity is a useful concept because it can be derived from a sample of existing data: one simply divides the sum of billed kWh by the sum of all the of Ft2 served by the meters in the sample. Residential EI is equivalent to the familiar concept of use per customer.[8]

> **Market Share, EUI and EI: An Example**
>
> Suppose there are 100 houses in the Railbelt and that 40 of them have electric water heaters, 50 have gas water heaters, and 10 have no water heaters. Suppose that each electric water heater uses 5000 kWh/yr, while each gas water heater consumes 20 Mcf of gas per year. Then:
> - The electric water heat EUI equals
>   5000 kWh/house/yr
> - The gas water heat EUI equals
>   20 Mcf/yr
> - The electric market share of the water heat market = 40/100 = 40%
> - The gas market share of the water heat market =
>   50/100 = 50%
> - The electric water heat energy intensity (EI) =
>   (40%) * 5000 = 2000 kWh/house/yr
> - The gas water heat (EI) =
>   (50%) * 20 = 10 Mcf/house/yr

- Utilization Rate is a measure of the frequency and duration of equipment use normalized to equal 1.0 in 1987. Utilization rate can change due to both lifestyle

[6] In general, market share collapses to one or the other of these concepts: In noncompetitive end uses (lights, frig, etc.) mode split =1 and share equals saturation, while in competitive uses (heating, cooking, etc.), saturation generally equals 1 and share equals mode split. In some end uses, such as clothes dryers, our concept of market share corresponds to neither saturation nor fuel mode split. But it is always equal to the product of the two. It is modelled this way to allow direct computation of consumer movements between fuels and between ownership and nonownership of an appliance.

[7] The exception being air conditioning.

[8] Interpretation of residential use per customer estimates computed from reported utility sales data is complicated by Alaska's current high rate of residential vacancy.

changes such as thermostat setback and technical fixes such as thermostat timers. Conceptually, utilization embodies all changes in consumption during the time period when the appliance stock is fixed. In practice, it is often impossible to draw a clear line between utilization changes and equipment changes.

The concepts of Market share, EUI, and EI have both stock and flow interpretations which are crucial to the evolution of the energy market. At any moment, the *stock average* values of these terms describe the structure of the market and lead to the level of total sales. All three terms are also used to measure the attributes of the *flow* of new capital (houses, buildings, and equipment) into the energy market. When used to describe the attributes of new equipment, the terms are known as marginal shares, marginal EUIs, and marginal EIs. For example, the average electric share of the Anchorage clothes dryer stock is 71%. This measures what people *own* (a stock concept). The initial marginal share used in our forecast is 68%. This is an estimate of what people are *buying* (a flow concept).

The difference between average and marginal shares and EUIs is generally the chief force acting on electric sales per customer. As every baseball player knows, if current performance falls short of average performance, the average will soon fall. Similarly, if no one builds electrically heated houses for 20 years, average electric heat market share will be pulled down toward zero.[9]

1.3.2 Central Energy Equation

The terms just described are combined to form a *central energy equation* which is at the core of every end use model:

$$\begin{aligned}\text{Sales}_{ijkn} = \text{Floorstock}_{jn} &* \text{Electric Market Share}_{ijkn} \\ &* \text{Energy Use Index}_{ijkn} \\ &* \text{Utilization Rate}_{ijkn}\end{aligned} \tag{1.1a}$$

where
i = fuel type
j = building type
k = end use
n = year

This equation says that in year n, sales of fuel i to building type j for end use k are equal to the type j floorstock times the fuel i market share for end use k times the use per appliance times the utilization rate of end use k appliances using fuel i. (1.1a) can be rewritten in terms of electric intensity EI by substituting the definition of EI for the terms (market share) * EUI:

$$\underset{\text{(kWh)}}{\text{Sales}_{ijkn}} = \underset{\text{(Ft2)}}{\text{Building Stock}_{jn}} * \underset{\text{(kWh / Ft2)}}{\text{Energy Intensity}_{ijkn}} * \text{Utilization Rate}_{ijkn} \tag{1.1b}$$

[9] Provided, of course, that there is some new construction occurring in the overall housing market.

Once sales by building type, end use, and fuel are computed, total sales are simply aggregations over the appropriate index variable. For example, if electricity is indexed by i=1 and single family homes by j=1, then electric sales to single family homes are written:

$$Sales_{1,1,n} = \sum_{k} Sales_{1,1,k,n} \tag{1.2}$$

The subscripts in the central energy equation point up the level of detail maintained by end use models. This detail is the chief advantage of the end use framework. Electricity use can change because of shifts in:

- **Floorstock type distribution.** Grocery stores use 5-10 times the electricity of warehouses.
- **Market share** within a building type. The de facto moratorium on electric heat in Fairbanks has caused a marked drop in measured use per customer during the last decade.
- **Technical efficiency (EUI)** of specific end use equipment. Federal law mandates a ~20 percent reduction in kWh per new refrigerator starting in 1991.
- **Utilization rate** of equipment. The Anchorage School District cut its ventilation end use electric consumption by >20% by using energy management systems to "put its buildings to bed at night."

> Central Energy Equation: Example
>
> Consider the use of headbolt heaters by Fairbanks residential customers. There are ~25,000 customers. End use survey data indicate that 31% of all customers have 1 heater and an additional 39% have 2. The total market share is
>
> Share = .31 + (2*.39) = 1.09
>
> On average, every house has 1.09 heaters. The EUI is a function of weather; under the assumptions of table 2.9, calculated EUI is 554 kWh per heater per year. Assume Utilization = 1.0. Then, total sales to the residential sector for the headbolt heater end use are:
>
> $$SALES = \underbrace{25{,}000}_{\text{floor-stock}} * \underbrace{1.09}_{\text{share}} * \underbrace{554}_{\text{EUI}} * \underbrace{1.0}_{\text{Util-ization}} = 15.1 \text{ GWh/yr}$$
>
> In this example the energy intensity (EI) = 1.09 * 554 = 604 kWh/household. Notice how EUI is a technological parameter, while EI is a summary statistic since nobody has exactly 1.09 heaters.

Through the central energy equation, end use models distinguish between these effects and keep separate track of their influence on total electric sales.

1.3.3 Model Logic

All end use models use some sort of central energy equation. In this sense they are accounting machines. The models used in this study[10] are significantly more sophisticated than this, however. In both of them, the energy equation is a final step of arithmetic. The bulk of the models' algorthims are devoted to determining the components of (1.1a): market share, technical efficiency (EUI), and utilization rate. Only floorstock is an exogenous input.

---

[10] The residential model is an enhanced version of the Lawrence Berkeley Labs Residential Energy Model. It has been re-christened the Alaska Residential Energy Model (AKREM). AKREM is written in FORTRAN 77, runs on an IBM-compatible microcomputer, requires a single ASCII input file, is in the public domain, and is available without charge from ISER. The commercial end use model is EPRI's COMMEND-PC 3.0. COMMEND is written in C, runs on an IBM/AT-compatible microcomputer, is copyrighted by EPRI, and is available free to EPRI members or for a license fee to others.

The Importance of Market Share in Total Sales is a function of several factors, as shown by the central energy equation. Neglecting Utilization, we can rewrite (1.1a) for a particular fuel (electricity) as:

$$G_{jk}=F_j*S_{jk}*E_{jk} \quad ; (k=\text{end use}, j=\text{bldg type}) \tag{1}$$

where G=sales, F=floorstock, S=market share, and E = EUI. The following propositions follow from either calculus or common sense:

- First, for any fixed k and j, $dG/dS = F*E$. The sensitivity of changes in sales to changes in market share is a function of EUI level. Changes in electric heating shares are more important than changes in clothes drying shares.
- Second, for k,j fixed, the elasticity of G with respect to S is fixed at one. That is, a given *relative* change in S is far more important if the level of S is high to start with. Uncertainty in estimates of the gas cooling share is unimportant because the level of the share is close to zero.
- Third, consider aggregation to building total sales figures:

$$G_j = \Sigma_k G_{jk} \tag{2}$$

$$dG_j/dS_{jk} = E_{jk}$$

$$(dG_j/dS_{jk})*(S_{jk}/G_j) = E_{jk} * (S_{jk}/G_j)$$

$$= (E_{jk}*S_{jk}) / G_j = G_{jk}/G_j \tag{3}$$

  That is, the elasticity of building sales with respect to one end use's market share equals the end use's share of building sales.
- Finally, consider aggregating across building types to arrive at total sales figures:

$$G = \Sigma_j F_j * G_j \tag{4}$$

  Algebra similar to (3) quickly shows that the elasticity of *total* sales with respect to market share of one end use in one building type is equal to:

$$(dG/dS_{jk})*(S_{jk}/G) = (F_j/F)*(G_{jk}/G_j) \tag{5}$$

  That is, the importance of a single market share to total sales is a function of the end use's share in building sales times the building's share in total sales.

In computing these components, the end use model subroutines function as simulation models with both engineering and behavioral aspects. A *very rough* sketch of the algorithms looks like this:[11]

- Market share (%) for each fuel/building type/end use combination is determined by evaluating a set of econometric choice equations. These equations are initially calibrated to reproduce initial estimates of actual marginal market shares (what people are buying and building). Marginal market shares evolve throughout the forecast in response to levelized operating and capital costs of available appliances as well as income. These life-cycle costs depend in turn on expected fuel prices, discount rates, and the technical efficiency of the equipment.

[11]Detailed descriptions of model logic may be found in (residential) Hirst 1978 and (commercial) McMenamin 1988??, McMenamin 1987.

- **EUIs** (kWh/Ft2 or kWh/appliance) are essentially determined by minimizing the life cycle cost of providing the end use service. This is accomplished by choosing an optimal point on an engineering curve which relates equipment cost to energy use. The optimal point is (partly) a function of the prevailing consumer discount rate. These discount rates are input to the model based on empirical obervation of past equipment purchases (Ruderman 1984). The high level of these disount rates attests to the fact that considerations other than life cycle cost minimization play a large role in consumer decisionmaking. For some commercial end uses, intertia factors also are used to model customer resistance to change. Marginal EUIs evolve throughout the forecast in response to changing prices and technological possibilities. Average EUIs are determined by tracking the flow of appliance retirements and purchases.

- **Utilization Rate** (%) is calculated by applying short-run elasticity coefficients to changes in electricity price.

- **Thermal Interaction** algorithms account for the effects of an increase in the load of one end use on the load of another. For example, interaction coefficients adjust the heat load upward (or the cooling load downward) if the lighting load drops. These interactions are only modelled in the commercial sector.

- **Vintage effects** are tracked and accounted for. Equation (1.1) yields correct sales calculations only when its components reflect stock average values for market shares and EUIs. When new equipment EUI and market share values differ from stock average values, the appliance stock age distribution and rate of turnover can be an important determinant of total energy sales. Our end use models are initialized with regional age distributions for buildings and appliances derived from the end use surveys. Together with retirement functions, these initial age distributions determine the flow of retiring units out of the equipment stock. As new equipment replaces old, the new EUI and market share values are "rolled in" to the averaging process, and the equipment age distribution is updated.

1.4 Treatment of Uncertainty

1.4.1 Use of Probability Tree Analysis

Alaska's volatile economy, energy price uncertainty, rapid technological change, and an immature gas distribution system all make the future level of electricity demand quite uncertain. We address this uncertainty explicitly through the use of a probability tree analysis. Our approach follows that used by Goldsmith (1988, chapter 3) to develop employment/household forecasts for input to this study. In consultation with the Power Authority, we developed alternatives for the following sets of critical assumptions assumed to affect demand:

- **H**: households and employment (3 alternatives)
- **P**: energy prices (3 alternatives)
- **D**: consumer preferences (discount rates) (2 alternatives)
- **T**: technological change (2 alternatives)
- **G**: natural gas market penetration (2 alternatives)

2. Residential Input Assumptions

2.1 Housing Stock

Residential energy use is largely determined by the size and composition of the residential housing stock. A model which estimates housing stock based upon the outputs of Goldsmith's (1988) projections of employment and households was constructed to project housing stock under three employment/households scenarios: Low (85% chance of being exceeded), Middle (50%), and High (15% chance of being exceeded).

2.1.1 Current Housing Stock

The composition of the residential housing stock for 1988 is presented in Table 2.1. These estimates are based on the best information available in the summer of 1988, but are subject to some error due to the transitional nature of the Railbelt housing market at the time.

RAILBELT RESIDENTIAL HOUSING STOCK
Thousands in mid 1988

		SINGLE FAMILY	MULTI FAMILY	MOBILE HOME	TOTAL	SECOND HOMES
ANCHORAGE	occupied	36.317	35.314	5.680	77.311	
	vacant	2.734	7.286	1.420	11.440	
	total	39.051	42.600	7.100	88.751	0.506
GREATER FAIRBANKS	occupied	15.511	6.713	2.276	24.500	
	vacant	0.990	2.391	0.569	3.950	
	total	16.501	9.104	2.845	28.450	0.195
KENAI PENINSULA	occupied	9.313	3.086	2.301	14.700	
	vacant	0.594	0.110	0.575	1.279	
	total	9.907	3.196	2.876	15.979	2.438
MATANUSKA SUSITNA	occupied	9.677	1.227	1.225	12.129	
	vacant	2.419	0.815	0.346	3.580	
	total	12.096	2.042	1.571	15.709	4.129
TOTAL	occupied	70.818	46.340	11.482	128.640	
	vacant	6.737	10.602	2.910	20.249	
	total	77.555	56.942	14.392	148.889	7.268

These housing unit figures have been adjusted for consistency with electric utility customer records and consequently do not conform to the actual housing stock counts within each region. Greater Fairbanks includes the Fairbanks Borough and the Southeast Fairbanks Census Area. Matanuska Susitna (MatSu) refers to the Borough, not including Eagle River. Calculations to allocate Eagle River variables to MEA service territory are available from ISER.

Table 2.1: Railbelt Residential Housing Stock

Residential Electric Market Shares
(Percent of Total Households)

AVERAGE

End Use	Anc	Fbx	Kenai	Matsu
Hot Water				
Single	14	34	56	46
Mult	27	28	33	50
Mobile	41	48	55	65
Refrigerator				
Single	103	103	103	103
Mult	103	103	103	103
Mobile	103	103	103	103
Freezer				
Single	57	63	74	83
Mult	57	63	74	83
Mobile	57	63	74	83
Cooking				
Single	71	67	52	68
Mult	85	100	73	100
Mobile	18	44	10	19
Dryer				
Single	76	82	67	82
Mult	56	51	64	25
Mobile	83	85	62	49

MARGINAL: Existing Stock Replacements

End Use	Anc	Fbx	Kenai	Matsu
Hot Water				
Single	14	34	56	46
Mult	27	28	33	50
Mobile	41	48	55	65
Refrigerator				
Single	103	103	103	103
Mult	103	103	103	103
Mobile	103	103	103	103
Freezer				
Single	57	63	74	83
Mult	57	63	74	83
Mobile	57	63	74	83
Cooking				
Single	71	67	52	68
Mult	85	100	73	100
Mobile	18	44	10	19
Dryer				
Single	68	82	54	66
Mult	51	51	51	20
Mobile	74	85	50	39

MARGINAL: New Construction

End Use	Anc	Fbx	Kenai	Matsu
Hot Water				
Single	5	17	30	23
Mult	10	14	30	25
Mobile	41	24	30	32
Refrigerator				
Single	103	103	103	103
Mult	103	103	103	103
Mobile	103	103	103	103
Freezer				
Single	66	63	74	83
Mult	66	63	74	83
Mobile	66	63	74	83
Cooking				
Single	50	67	52	68
Mult	75	100	73	100
Mobile	18	44	10	19
Dryer				
Single	68	82	54	66
Mult	51	51	51	20
Mobile	74	85	50	39

Table 2.8: Residential Electric Market Shares, Other Appliances

2.4 EUI Values

2.4.1 EUI Estimation Procedure

Current residential EUI values were developed from a number of sources including:

- **National appliance data** developed for the U.S. Department of Energy by Lawrence Berkeley Laboratory;
- The **AKWARM heat loss model** and data sets developed for the State of Alaska's thermal standards analysis;
- **Vintage Profiles of the Railbelt appliance stock** derived from the ISER end use survey;
- **Usage data** from the end use survey.

Because the Railbelt housing stock is known with reasonably good precision, we treated the EUI values as the main calibration levers of the residential model. The numbers were developed on an interactive spreadsheet with the twin goals of (1) maintaining a reasonable foundation in engineering and end use data and (2) accurately reproducing control data on total sales by region.

Electric heat EUIs are difficult to develop because of the multiple heating fuel phenomenon described in section 2.2.3 and because of the lack of good data on thermal integrity. As stated in section 2.2.3, our analysis was conducted on an "all-electric equivalent" basis. We used an initial estimate of consumption derived directly from the AKWARM thermal model using average housing sizes of 1700 Ft2 (single), 1000 Ft2 (multi, mobile)[10] and the proposed state thermal performance standards for heat loss per Ft2, which are generally believed to be comparable to the current stock average of electrically heated construction.

These initial estimates of 18,508 kWh/yr for the southern regions agreed almost perfectly with the Figure of 18,511 kWh/yr determined from regression analysis of the end use survey data (see Appendix A). During calibration, Fairbanks values were adjusted up to reflect a colder climate, then down to reflect better insulation levels and to retain consistency with overall sales data. Kenai numbers were adjusted down and MatSu numbers were adjusted up to be consistent with overall sales data. These heat EUIs are substantially less than the Figures used in some previous Railbelt electric demand forecasts (Scott 1983 suggested 40,000 kWh for Anchorage, 53,000 for Fairbanks; Goldsmith & Huskey 1980 suggested 32,000).

Water Heat EUIs were developed by using the demand Figure of 18 gal/day/person developed by Lawrence Berkeley labs from a database of 11,000 metered water heaters, and applying the appropriate household size (by housing type) and water inlet temperatures.

Refrigerator and Freezer EUIs were developed from nationally reported consumption values (Geller 1988). We adjusted these down to account for Alaska's younger (hence more efficient) appliance stock. The final values used are consistent with our calculated Railbelt stock average efficiency of 5.61 (Energy Factor) and with the Berkeley/DOE technology curve for refrigerators (described below).

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[10] These house sizes were determined from the Anchorage Property Appraisal Tape (N=59,000). They agree well with residential end use survey data.

Cooking and Drying EUIs were taken from Geller 1988. The Anchorage and Fairbanks values were adjusted down to reflect the increased number of meals eaten out in these regions as determined from the end use survey.

Lighting numbers are taken from Geller 1988, the AKREM default data base, and simple engineering calculations. Although Alaskans receive the same amount of total annual sunlight as the rest of the U.S., most of our late night (summer) light arrives while we are asleep. In contrast, our daytime (winter) darkness is felt during waking hours. This imbalance implies a higher Alaska demand for lighting.

EUIs for the **Miscellaneous End Use** were developed by spreadsheet analysis of survey data, reproduced in Table 2.9. Our separate spreadsheet analysis of engine block heater use (Table 2.10) derives regional EUIs less than half as large as those used by Scott (1983) and Goldsmith (1980). Tables 2.11 through 2.14 present the final residential EUI numbers in a calibration worksheet framework.

Miscellaneous End Use Consumption

Regional Estimates

	kWh / Appliance			Saturations				kWh per customer				
Appliance	kWh	or kW	* Hrs	Anc	Fbx	Kenai	Matsu	Anc	Fbx	Ken	Mat	Notes
fan/pump	400			1.200	1.200	1.200	1.200	480	480	480	480	1
clocks	60			1.000	1.000	1.000	1.000	60	60	60	60	
Iron	120			1.000	1.000	1.000	1.000	120	120	120	120	
Dishwash	150			0.810	0.520	0.600	0.720	122	78	90	108	1
Microwave	30			0.820	0.810	0.810	0.820	25	24	24	25	1
Stereo	75			1.000	1.000	1.000	1.000	75	75	75	75	
TV	300			1.300	1.700	1.700	1.800	390	510	510	540	1
Toaster	20			1.000	1.000	1.000	1.000	20	20	20	20	
Vacuum	30			1.000	1.000	1.000	1.000	30	30	30	30	
Washer	60			0.880	0.840	0.860	0.920	53	50	52	55	1
Computer	20			0.250	0.240	0.210	0.190	5	5	4	4	
Bolt Htr	[See detailed calculations Table 2.10]							108	604	110	114	2
Jacuzzi	1600			0.042	0.022	0.015	0.047	67	35	24	75	1,3
Sauna	1600			0.046	0.028	0.029	0.047	74	45	46	75	1,3
Waterbed	1200			0.260	0.240	0.221	0.310	312	288	265	372	1,4
Heat Tape	400	2	200	0.025	0.006	0.030	0.009	10	2	12	4	1
		Total Misc. kWh:						1950	2427	1923	2157	

Notes:

1 Saturations from ISER 1987 End Use Survey
2 See Separate table for Block Heater Analysis
3 kWh per yr from Battelle, 1983
4 kWh per yr Estimate from ISER regression
compares with 1440 engineering analysis

Table 2.9: Miscellaneous Appliance EUI Derivation

Engine Block Heater Analysis

		ANC	FBX	KEN	MAT
Ownership (1)					
fraction owning:	1	0.25	0.31	0.16	0.31
	2	0.19	0.39	0.25	0.24
Total Saturation:		0.63	1.09	0.66	0.79
Use patterns among users:					
1: used if <0 (-5 av)		0.28	0.52	0.31	0.45
2: used if <20 (10 av)		0.72	0.48	0.69	0.55
Weather Data (2)					
hours < -5		183	1571	183	183
hours < 10		905	2684	905	905
Engineering Assumptions:					
Hours enabled = .5 * weather					
group 1		92	786	92	92
group 2		453	1342	453	453
Duty Factor:					
group 1		0.5	0.5	0.5	0.5
group 2		0.4	0.4	0.4	0.4
Conclusions:					
Time on:					
group 1		46	393	46	46
group 2		181	537	181	181
average		143	462	139	120
Capacity (kW):		1.2	1.2	1.2	1.2
Consumption (kWh): (per device)		172	554	167	144
Consumption per household		108	604	110	114

Notes:
1 Ownership and usage patterns from ISER end use survey.
2 Weather Data from NWS Bin Data for Eielson and Elmendorf AFB

Table 2.10: Engine Block Heater EUI Analysis

Final Residential EUIs **Region: ANC**

Total Sales Calculated: 689
Total Sales from Data: 670

End Use	House Type	House Stock	Current Market Share	EUI (kWh/yr)	Sales GWh
HEAT	Single	36.3	0.06	18429	40.2
	Multi	35.3	0.24	10000	84.8
	Mobile	5.7	0.05	10840	3.1
WATR	Single	36.3	0.14	5300	26.9
	Multi	35.3	0.27	4770	45.5
	Mobile	5.7	0.4	4180	9.5
FRIG	Single	36.3	1.03	1200	44.9
	Multi	35.3	1.03	1100	40.0
	Mobile	5.7	1.03	1000	5.9
FREZ	Single	36.3	0.54	1000	19.6
	Multi	35.3	0.54	1000	19.1
	Mobile	5.7	0.54	1000	3.1
COOK	Single	36.3	0.71	650	16.8
	Multi	35.3	0.85	650	19.5
	Mobile	5.7	0.17	650	0.6
DRY	Single	36.3	0.75	1100	30.0
	Multi	35.3	0.56	1100	21.8
	Mobile	5.7	0.79	1100	4.9
LITE	Single	36.3	1	1500	54.5
	Multi	35.3	1	1000	35.3
	Mobile	5.7	1	1000	5.7
MISC	Single	36.3	1	1950	70.8
	Multi	35.3	1	1950	68.9
	Mobile	5.7	1	1950	11.1
VACANT	Single	2.7	1	600	1.6
	Multi	7.3	1	600	4.4
	Mobile	1.4	1	600	0.9

Table 2.11: Anchorage Residential EUI Calibration Worksheet

Final Residential EUIs **Region: FBX**

Total Sales Calculated: 219
Total Sales from Data: 207

End Use	House Type	House Stock	Current Market Share	EUI (kWh/yr)	Sales GWh
HEAT	Single	15.5	0.04	20000	12.4
	Multi	6.7	0.09	10000	6.0
	Mobile	2.3	0.02	10000	0.5
WATR	Single	15.5	0.34	5302	28.0
	Multi	6.7	0.28	4770	9.0
	Mobile	2.3	0.47	4183	4.5
FRIG	Single	15.5	1	1200	18.6
	Multi	6.7	1	1100	7.4
	Mobile	2.3	1	1000	2.3
FREZ	Single	15.5	0.63	1000	9.8
	Multi	6.7	0.63	1000	4.2
	Mobile	2.3	0.63	1000	1.4
COOK	Single	15.5	0.67	650	6.8
	Multi	6.7	1	650	4.4
	Mobile	2.3	0.44	650	0.7
DRY	Single	15.5	0.82	1100	14.0
	Multi	6.7	0.51	1100	3.8
	Mobile	2.3	0.85	1100	2.1
LITE	Single	15.5	1	1500	23.3
	Multi	6.7	1	1000	6.7
	Mobile	2.3	1	800	1.8
MISC	Single	15.5	1	2000	31.0
	Multi	6.7	1	2000	13.4
	Mobile	2.3	1	2000	4.6
VACANT	Single	1.0	1	600	0.6
	Multi	2.4	1	600	1.4
	Mobile	0.6	1	600	0.3

Table 2.12: Fairbanks Residential EUI Calibration Worksheet

Final Residential EUIs   Region: KENAI

Total Sales Calculated: 165
Total Sales from Data: 153

End Use	House Type	House Stock	Current Market Share	EUI (kWh/yr)	Sales GWh
HEAT	Single	9.3	0.3	10000	27.9
	Multi	3.1	0.28	7500	6.5
	Mobile	2.3	0.05	8000	0.9
WATR	Single	9.3	0.56	5302	27.7
	Multi	3.1	0.33	4770	4.9
	Mobile	2.3	0.55	4183	5.3
FRIG	Single	9.3	0.96	1200	10.7
	Multi	3.1	0.96	1100	3.3
	Mobile	2.3	0.96	1000	2.2
FREZ	Single	9.3	0.73	1000	6.8
	Multi	3.1	0.73	1000	2.3
	Mobile	2.3	0.73	1000	1.7
COOK	Single	9.3	0.52	800	3.9
	Multi	3.1	0.73	800	1.8
	Mobile	2.3	0.1	800	0.2
DRY	Single	9.3	0.67	1100	6.9
	Multi	3.1	0.64	1100	2.2
	Mobile	2.3	0.62	1100	1.6
LITE	Single	9.3	1	1500	14.0
	Multi	3.1	1	1000	3.1
	Mobile	2.3	1	800	1.8
MISC	Single	9.3	1	1980	18.4
	Multi	3.1	1	1980	6.1
	Mobile	2.3	1	1980	4.6
VACANT	Single	0.6	1	600	0.4
	Multi	0.1	1	600	0.1
	Mobile	0.6	1	600	0.3

Table 2.13: Kenai Residential EUI Calibration Worksheet

Final Residential EUIs　　　　Region: MAT

Total Sales Calculated: 182
Total Sales from Data: 192

End Use	House Type	House Stock	Current Market Share	EUI (kWh/yr)	Sales GWh
HEAT	Single	9.7	0.24	23000	53.2
	Multi	1.2	0.47	16000	9.2
	Mobile	1.2	0.2	12000	2.9
WATR	Single	9.7	0.46	5302	23.6
	Multi	1.2	0.5	4770	2.9
	Mobile	1.2	0.64	4183	3.3
FRIG	Single	9.7	1.03	1200	12.0
	Multi	1.2	1.03	1100	1.4
	Mobile	1.2	1.03	1000	1.3
FREZ	Single	9.7	0.83	1000	8.0
	Multi	1.2	0.83	1000	1.0
	Mobile	1.2	0.83	1000	1.0
COOK	Single	9.7	0.52	800	4.0
	Multi	1.2	0.73	800	0.7
	Mobile	1.2	0.1	800	0.1
DRY	Single	9.7	0.82	1100	8.7
	Multi	1.2	0.25	1100	0.3
	Mobile	1.2	0.49	1100	0.7
LITE	Single	9.7	1	1500	14.5
	Multi	1.2	1	1000	1.2
	Mobile	1.2	1	800	1.0
MISC	Single	9.7	1	2400	23.2
	Multi	1.2	1	2400	2.9
	Mobile	1.2	1	2400	2.9
VACANT	Single	2.4	1	600	1.5
	Multi	0.8	1	600	0.5
	Mobile	0.3	1	600	0.2

Table 2.14: MatSu Residential EUI Calibration Worksheet

3. Commercial Input Assumptions

The commercial[1] sector is far more heterogeneous than the residential, and hence far more difficult to characterize via summary statistics. Buildings vary in size by a factor of ~100, are put to hundreds of different uses, and contain a multitude of electric equipment which defies characterization as a set of appliances. While we use the same analytical approach in both sectors, it must be recognized that the point estimates used to represent the "stylized facts" of the commercial market are forced to summarize far more variation than their residential counterparts.

3.1 Commercial Floor Space

We used city and borough property appraisal files to compile an inventory of the Railbelt nonresidential building stock, classified by size, age, and space type.

3.1.1 Current Floorstock Composition

Figure 3.1 shows the 1988 regional breakdown of Railbelt floorstock. Figures 3.2 through 3.5 show our estimates of the 1987 Railbelt floorstock by region and building type. Figure 3.6 affords a comparison of the commercial floorstock composition across regions. It shows the percentage of each building type relative to regional total floorstock, with all four regions clustered together for comparison. For example, Fairbanks has 36% of its commercial space devoted to warehousing and storage buildings, reflecting its status as a regional distribution center. Anchorage, meanwhile, has twice the relative office space of its sister regions, reflecting its role as a financial, personal, and legal services hub.

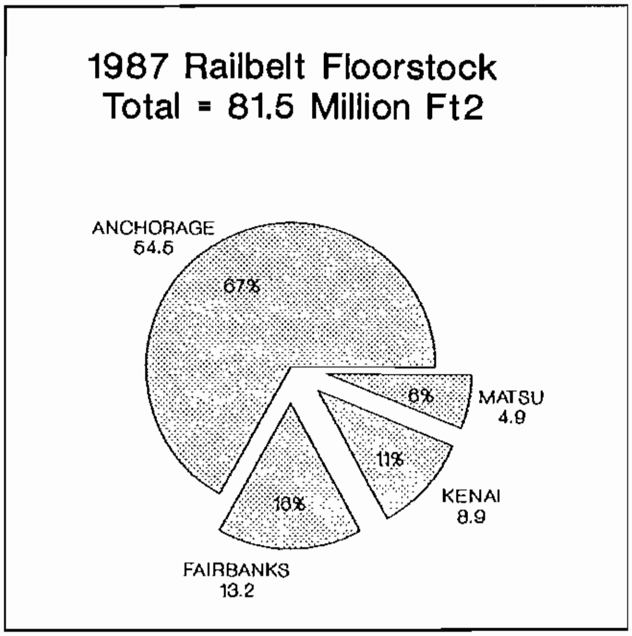

Figure 3.1: 1987 Railbelt Floorstock

Since our floorstock estimates are based on an actual building count, we know they are low. Without an independent control total number, however, it is difficult to assess the degree of the undercount. To check the reasonableness of the total floorstock numbers for each region, we compared our direct estimates to those obtainable from national ratios of Ft2/Population and Ft2/Employee taken from the 1983 NBECS data.[2] Table 3.1 presents these comparisons.

[1] A more accurate term would be nonresidential buildings, since the stock includes government, education, and public assembly buidings. The term commercial is taken from the utility rate class to which most of these buildings belong for billing purposes.

[2] DOE's Nonresidential Buildings Energy Consumption Survey is a comprehensive assessment of ~5000 buildings, completed in 1979 and again in 1983. NBECS ratios by building type can be found in McMenamin 1988.

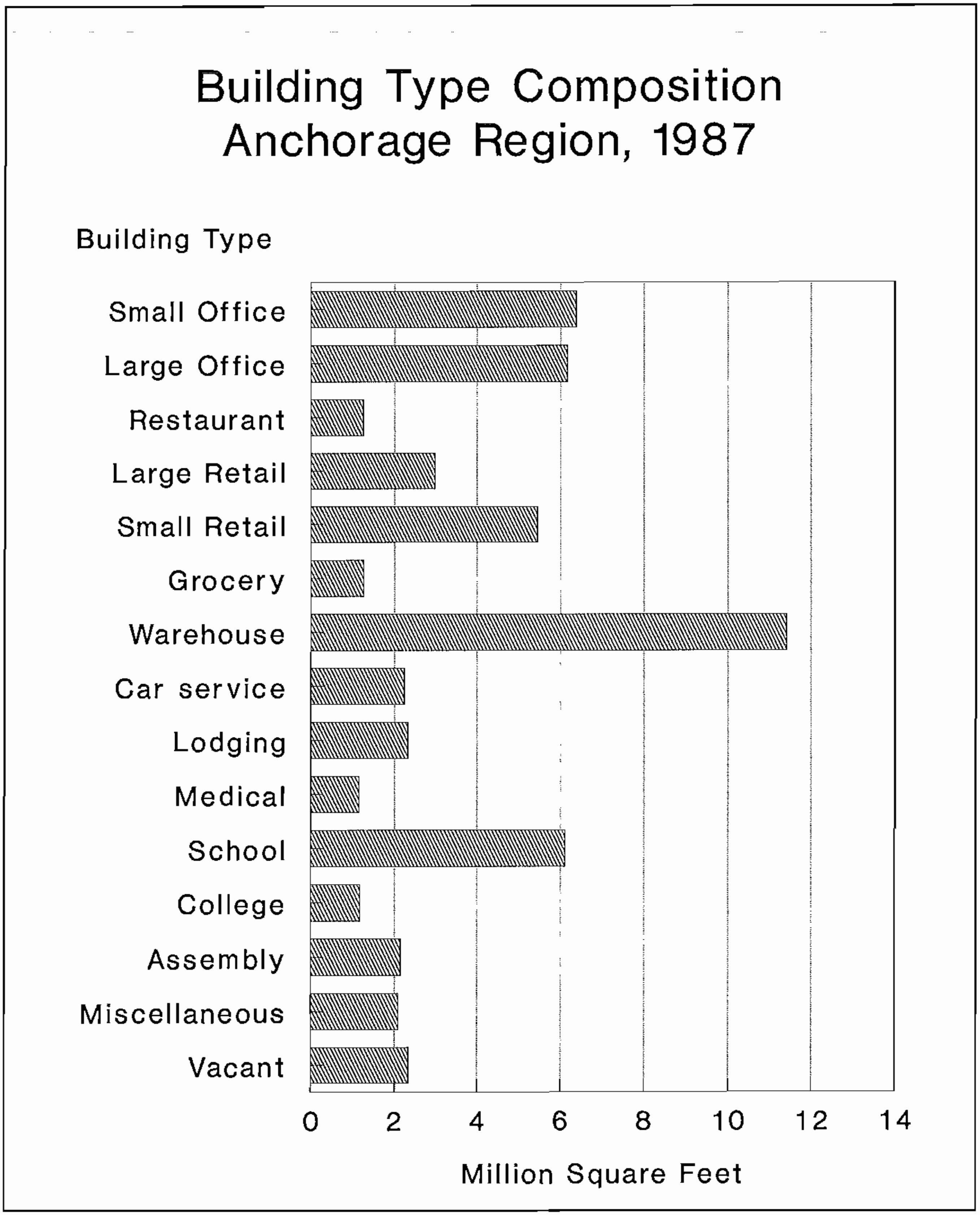

Figure 3.2: 1987 Anchorage Floorstock

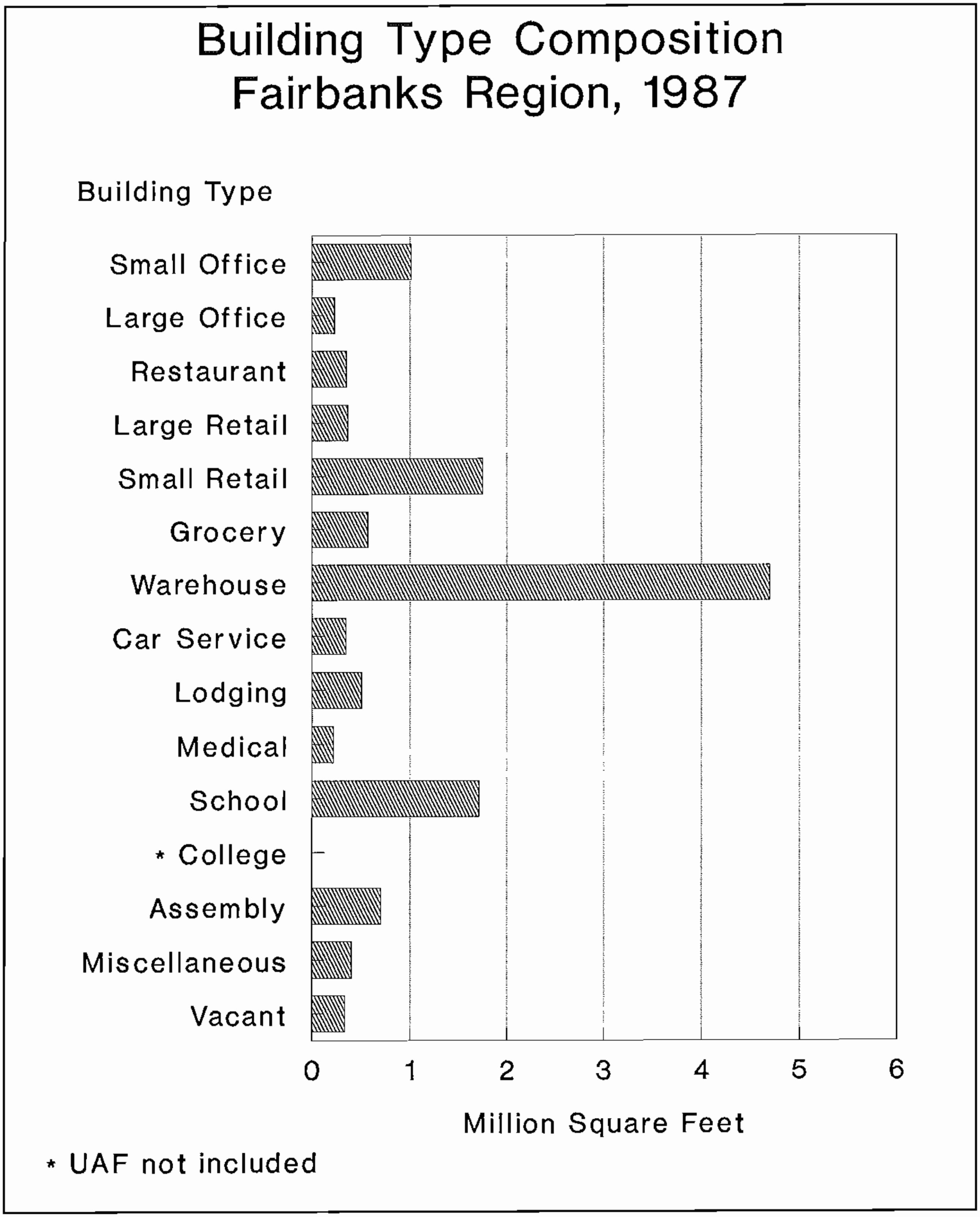

Figure 3.3: 1987 Fairbanks Floorstock

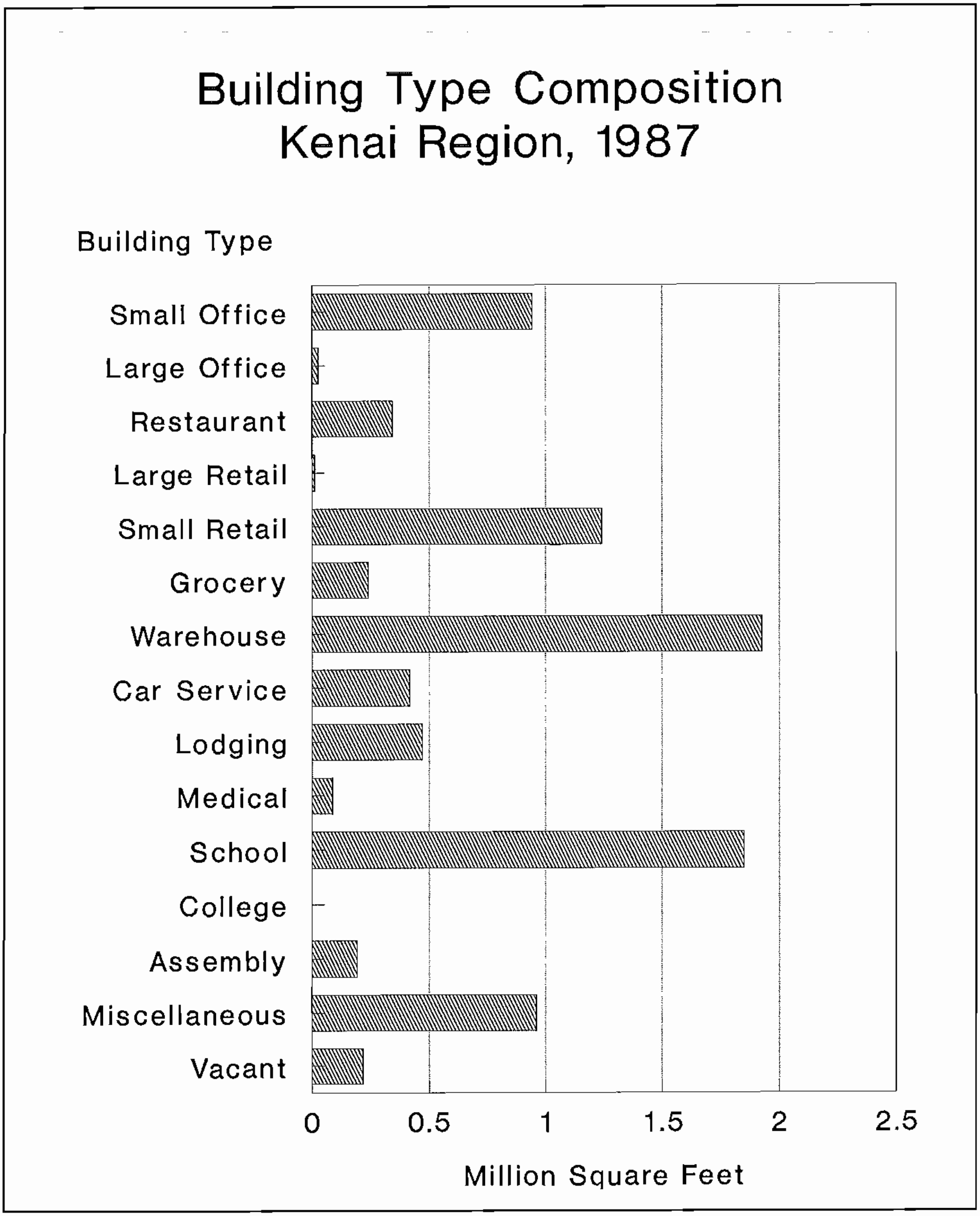

Figure 3.4: 1987 Kenai Floorstock

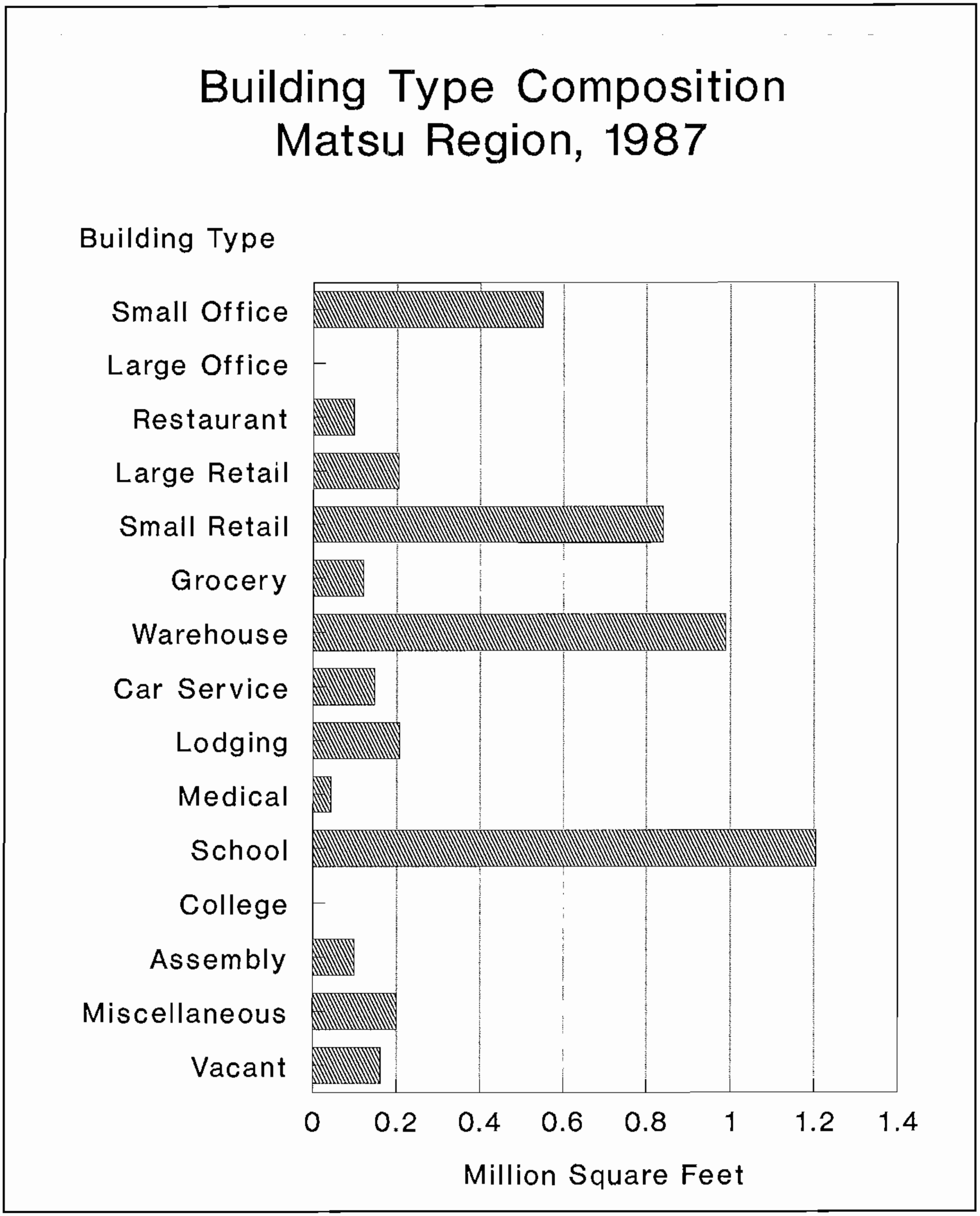

Figure 3.5: 1987 MatSu Floorstock

3.2 Electric Market Shares

In today's Railbelt commercial market, the only truly competitive end uses are space and water heating. While gas cooling technologies do exist packaged in rooftop multi-zone air handling units, we found no field evidence of these units in Alaska. Two large Anchorage building complexes have gas-fired absorption chillers, but these sites are highly unrepresentative of the building population. Electricity's high cooling market share is hardly surprising, given the low number of cooling degree days in the region. Cooking is another end use for which gas and electricity can both be used. However, we know of no empirical evidence that commercial cooking equipment choice is sensitive to relative fuel prices. In most commercial kitchens, gas is used on ranges, ovens, and steamers, while electricity powers deep fat fryers, grills, and other specialized means of delivering heat. We therefore model the cooking end use as noncompetitive.[5]

3.2.1 Average and New Equipment Fuel Shares

Table 3.2 shows our estimates of stock average and new equipment heat and hot water electric shares by building type and region. The new equipment shares are initial values; the COMMEND model uses them to calibrate a set of choice equations. The new equipment share values are then re-computed each year to reflect changes in life-cycle costs.

We collected electric market share data through our on-site commercial survey (N=135, Ft2=6 million) and a brief mail survey (N=596, Ft2=9.5 million). The individual data records were combined into area-weighted average shares by region and building type[6]. With 4 regions and 14 building types, coverage of individual cells (region/building type combinations) was somewhat thin. However, we elected to use the disaggregated data rather than go through another complicated weighted averaging process and throwing away some information about the differences in shares across building types.

There is even less data to support an estimate of new commercial building electric heat shares than there is in the residential sector. Adams Morgenthaler & Co. suggests that the current share is "less than one percent"; however, the amount of recent new commercial construction is so small as to be an unreliable guide for the future. In estimating new building heat shares we have again taken the conservative position that there will continue to be some long-run demand for electric heat. Especially in small buildings, the capital cost of a gas installation can be greater than a first glance might indicate. For example, current building code requires that a separate space be set aside in the building for any heating system of greater than 400 kBtu/h. Our calculations based on the estimated costs of heating systems indicate that the cost of this boiler room space exhibits tremendous economies of scale and can be prohibitive for small enough buildings.

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[5] Commercial clothes drying is another potentially competitive end use; it is too insignificant to warrant separate classification in the model.

[6] We have a strong hypothesis, as yet formally untested, that electric heat share is strongly and negatively correlated with building size. In larger buildings, commercial customers can take advantage of scale economies in the capital and design costs of fossil heating systems. In addition, the absolute payoff from attention to this cost area becomes large enough to justify management's attention to a life-cycle cost approach to heating system choice. If our hypothesis is true, it implies that electric market shares of commercial heat energy are substantially lower than electric shares of commercial heat customers.

As the end use breakdown of sales (Figure 1.2) suggests, the importance of the heat share parameter is far less important in the commercial sector than in the residential. No matter what fuel is chosen to run the heating system, electricity does much of the actual heating in many buildings through lights and office equipment.

We also project a continuing significant electric share of the commercial hot water *equipment* market. Many office and retail buildings use small point-of-use electric water heaters in lavatory areas with low water demand because they avoid the need for both gas piping and exhaust stacks, both of which can be very expensive to install relative to the hot water demand served. It may be be the case, however, that while electric hot water heaters hold a large portion of the market in terms of capacity or *square feet served*, their share of delivered hot water *energy* is appreciably lower. To the extent that this phenomenon is a function of building type, it is automatically controlled for in the COMMEND model.

Commercial Electric Market Shares

(Percent of Total Square Feet)

HEATING

Building Type	Anc	Fbx	Kenai	Matsu
Small Office				
Average	5	1	15	4
New Equipment	5	1	5	4
Large Office				
Average	2	1	15	4
New Equipment	2	1	15	4
Restaurant				
Average	2	6	14	3
New Equipment	2	6	10	3
Large Retail				
Average	18	0	15	3
New Equipment	5	0	10	3
Small Retail				
Average	26	0	15	3
New Equipment	5	0	10	3
Grocery				
Average	0	0	0	0
New Equipment	0	0	0	0
Warehouse				
Average	8	0	15	0
New Equipment	8	0	10	0
Car Service				
Average	7	0	0	0
New Equipment	7	0	0	0
Lodging				
Average	0	50	20	0
New Equipment	0	10	20	0
Medical				
Average	0	0	20	0
New Equipment	0	0	10	0
School				
Average	0	0	10	0
New Equipment	0	0	10	0
College				
Average	0	0	10	0
New Equipment	0	0	10	0
Assembly				
Average	0	24	14	50
New Equipment	0	24	10	50
Miscellaneous				
Average	5	0	0	100
New Equipment	5	0	0	100
Vacant				
Average	5	1	15	4
New Equipment	5	1	15	4
87 Floorstock Weighted Average				
Average	7	4	13	7
New Equipment	5	1	14	4

HOT WATER

Building Type	Anc	Fbx	Kenai	Matsu
Small Office				
Average	17	79	57	17
New Equipment	17	79	57	17
Large Office				
Average	13	43	57	17
New Equipment	13	43	57	17
Restaurant				
Average	9	38	17	33
New Equipment	9	38	17	33
Large Retail				
Average	43	100	50	4
New Equipment	43	100	50	4
Small Retail				
Average	47	14	50	4
New Equipment	47	14	50	4
Grocery				
Average	27	100	0	0
New Equipment	27	100	0	0
Warehouse				
Average	32	26	53	25
New Equipment	32	26	53	25
Car Service				
Average	24	86	20	100
New Equipment	24	86	20	100
Lodging				
Average	4	82	100	0
New Equipment	4	82	100	0
Medical				
Average	0	0	100	0
New Equipment	0	0	100	0
School				
Average	0	10	100	0
New Equipment	0	10	100	0
College				
Average	100	100	100	100
New Equipment	100	100	100	100
Assembly				
Average	9	74	54	100
New Equipment	9	74	54	100
Miscellaneous				
Average	25	100	30	100
New Equipment	25	100	30	100
Vacant				
Average	17	79	57	17
New Equipment	17	79	57	17
87 Floorstock Weighted Average				
Average	24	42	61	18
New Equipment	17	79	66	17

Table 3.2: Commercial Electric Market Shares

3.3 EUI Values

Energy Use Index values (EUIs) measure annual energy use per square foot of floor space for a particular space type, end use, and fuel. Along with floorstock and market share, the EUI values form the core of the COMMEND model. Together with capital cost and tradeoff data, discussed below, EUI estimates define the engineering boundaries within which the model operates.

Commercial EUIs are difficult to develop, for two reasons:

- Because they are end-use specific, EUIs cannot be measured from market data such as utility bills. They can only be measured by installing expensive metering equipment.[7]
- Because they are measures of energy use--as opposed to power demand--EUIs cannot be easily developed from a simple inventory of nameplate kW ratings such as that provided by a thorough on-site survey.

3.3.1 EUI Estimation Procedure

We used a combination of the following data and techniques, listed in order of importance, to develop the Railbelt EUI estimates used in COMMEND:

- on-site survey data
- mail survey data
- engineering calculations
- existing estimates from other regions of the United States
- building simulation modeling
- educated guesswork

1. We began the EUI estimation process by computing average **energy intensities** (overall building kWh/Ft^2) for each building type from the on-site and mail survey data. These data are useful starting points because they are the only control totals available at the building type level. (The next available level of control totals is aggregate total sales.) Table 3.3 presents these EI estimates.

2. Calculations based on the on-site survey data records were performed to determine the likely **distribution of the total EIs across end uses.** The survey provided direct measurement of installed kW by end use. Technical utilization rates were judgmentally estimated for both occupied and unoccupied time periods. For some end uses, such as lighting, this was a straightforward exercise as the survey provided operating hours data. For others, such as hot water, the load factor during operating hours is far less than one. In these cases we used engineering judgment and refered to metered end use studies such as Cleary 1986.

3. To compute the EUI values for **noncompetitive uses** (all except space and water heat), we applied the distribution from step 2 to the EIs determined in step 1.

[7]Several commercial end use metering projects have been undertaken during the past 5 years. Last year Bonneville Power spent over 1 million dollars metering 10 commercial buildings. See Synergic Resources, 1986 for an overview of metering projects and Cleary, 1986 for an in-depth look at metered data from Seattle.

Estimated Electric Intensities for the Railbelt Region

BLDG TYPE	MAIL SURVEY EI	N	ANNUAL	AREA	STD	ONSITE SURVEY EUI	N	ANNUAL	AREA	STD	WTD AVG	ONSITE CALC
SMO	18.0	45	5,209,560	289,584	8.7	17.9	15	2,148,386	119,818	8.6	18.0	18.0
LGO	20.0	9	9,215,088	461,300	9.2	22.5	6	23,511,017	1,043,858	3.9	22.1	20.2
RES	36.9	20	4,426,536	120,100	26.6	28.6	8	1,417,141	49,616	15.3	33.1	43.9
LGR	13.5	2	820,488	61,000	2.3	15.6	10	9,365,821	602,192	7.5	15.5	31.4
SMR	13.3	28	1,122,264	84,600	8.5	17.2	4	488,809	28,497	11.4	14.8	17.7
GRC	53.5	2	278,112	5,200	7.0	41.6	5	3,676,670	88,298	20.4	42.0	70.4
WRH	8.2	43	3,901,260	476,052	7.9	7.1	13	1,106,042	154,837	4.5	7.8	22.5
CAR	17.4	14	966,912	55,640	11.4	17.6	7	503,842	28,665	13.4	17.5	13.5
LDG						28.7	4	14,130,142	492,550	4.1	28.7	20.6
MED	21.7	9	2,834,472	130,754	5.1	17.8	1	562,276	31,532	ERR	20.4	13.4
SCH	9.1	13	6,272,040	691,400	4.5	9.5	5	5,887,011	617,225	1.5	9.4	15.0
COL						27.2	1	2,514,740	92,355	ERR	27.2	27.7
ASB	16.5	11	3,065,928	185,884	7.9	37.6	2	15,214,235	404,806	4.4	33.6	42.9
MSC						5.7	3	153,379	26,832	2.2	5.7	
VCT						11.9	1	16,126	1,350	ERR	11.9	1.6

Terms:

EI	Electric Intensity = ANNUAL surveyed Kwh / total surveyed AREA
N	Useable sample size after elimination of outliers
ANNUAL	sum over sample points of measured Kwh
AREA	sum over sample points of measured or reported Ft2
STD	Standard deviation of individual building EIs about building-type average
WTD AVG	Weighted average of Onsite and Mail results; Onsite weighted by 2 to reflect better data quality
ONSITE CALC	Engineering calculation of EI performed off ONSITE survey data records and averaged.

Table 3.3: Measured Electric Energy Intensities

4. EUI values for heat were developed from building simulation analysis of prototype buildings. Since we could not simulate every building type, we used the simulations as a benchmark to which we could scale up the relative EUI values from national data sets developed by COMMEND users.[8] Water heat EUIs were taken directly from the "COMMEND-cold climate" series developed by COMMEND users.

5. We made several adjustments to the base EUI estimates for Fairbanks. We increased heating, cooking, and misc. EUIs by 10%, 30%, and 1 kWh/Ft2 respectively to account for colder weather (tempered by better insulation), lack of gas, and head bolt heaters. The cooking EUI adjustment for Fairbanks was based on the fact that we modeled cooking as a noncompetitive end use, but derived the base EUI for cooking from survey data from sites at which some gas was generally used.

How many kWh/yr do "One square foot of headbolt heater" consume? The onsite survey showed an average of 1.4 watts headbolt heater capacity per Ft2 floorstock. Weather Service BIN data show 2259 hours below 0°F in Fairbanks. Assuming 50% of the heaters are on during these hours each operating with a 50% duty cycle implies annual consumption of .8 kWh per Ft2.

[8] McMenamin 1988, p. 5-23.

6. Finally, we considered the relationship of **new building EIs** to the stock average. Simple regressions of the form

$$\log(EI_j) = C_j + a_j{*}t, \qquad \text{where } t = \text{year built and } j \text{ indexes building types,} \tag{3.2}$$

were performed on the on-site survey data for each separate building type j and for the pooled sample of all building types taken together. The estimated a_j gives the trend rate of change in energy intensity since 1970. The pooled sample trend coefficient was -.0135, implying an average annual decrease in EI of 1.35% since 1970. Since market shares appear to have risen and fallen during this time period, we felt that the data supports a modest reduction in EUI values for new buildings. We performed this reduction on an end use basis, increasing the EUI in the cooking and miscellaneous end uses to reflect obvious trends in office and kitchen automation.

3.3.2 EUI Estimates

Tables 3.4 and 3.5 show the final EUI estimates input to COMMEND. Multiplied together, the estimated electric market shares and EUI values developed above yield a complete set of electric Energy Intensity estimates broken down by end use, building type, and region. These four "market snapshots" are presented in Figures 3.9 through 3.12. They represent the distilled knowledge gained from the end use survey data.

Energy Use Index Values (EUIs)

Southcentral Regions

(Kwh/Square Foot/Year)

AVERAGE

Building Type	Heating	Cooling	Vent	Hot Water	Cooking	Refrig	Lighting	Misc
Small Office	9.0	0.5	1.8	1.0	0.0	0.3	9.1	3.3
Large Office	9.0	0.7	5.3	1.0	0.0	0.0	13.3	2.5
Restaurant	9.5	2.1	4.4	7.0	8.2	8.6	7.7	1.2
Large Retail	6.3	1.3	1.7	0.8	0.0	0.1	10.6	1.4
Small Retail	6.3	0.2	1.0	0.8	0.0	1.0	7.4	1.8
Grocery	14.4	1.9	1.6	1.2	1.1	22.4	10.0	4.9
Warehouse	5.4	0.0	0.8	0.8	0.0	2.8	3.1	0.9
Car Service	7.2	0.1	1.7	1.0	0.0	0.1	11.2	3.8
Lodging	9.0	2.8	2.8	3.0	2.3	2.8	8.2	3.5
Medical	15.3	0.6	6.5	2.8	0.3	1.5	10.6	1.1
School	10.4	0.0	2.6	1.8	0.1	0.2	6.0	0.5
College	9.0	4.0	4.2	1.8	0.5	0.5	12.5	0.6
Assembly	9.0	3.0	4.0	1.0	0.6	1.4	10.1	2.5
Miscellaneous	9.0	1.5	2.6	0.9	0.0	0.1	10.6	0.8
Vacant	8.1	0.2	2.5	0.4	0.0	0.1	2.0	0.4

NEW EQUIPMENT

Building Type	Heating	Cooling	Vent	Hot Water	Cooking	Refrig	Lighting	Misc
Small Office	7.8	0.4	1.6	1.0	0.0	0.2	7.9	3.6
Large Office	7.8	0.6	4.6	1.0	0.0	0.0	11.6	2.7
Restaurant	8.3	1.8	3.8	7.0	9.5	7.5	6.7	1.4
Large Retail	5.5	1.1	1.5	0.8	0.0	0.0	9.2	1.5
Small Retail	5.5	0.2	0.9	0.8	0.0	0.9	6.5	2.0
Grocery	12.5	1.6	1.4	1.2	1.2	19.5	8.7	5.4
Warehouse	4.7	0.0	0.7	0.8	0.0	2.4	2.7	1.0
Car Service	6.3	0.1	1.5	1.0	0.0	0.1	9.7	4.2
Lodging	7.8	2.4	2.4	3.0	2.7	2.4	7.1	3.9
Medical	13.3	0.5	5.6	2.8	0.3	1.3	9.2	1.2
School	9.1	0.0	2.2	1.8	0.1	0.2	5.2	0.6
College	7.8	3.4	3.6	1.8	0.5	0.4	10.9	0.6
Assembly	7.8	2.6	3.5	1.0	0.7	1.2	8.8	2.7
Miscellaneous	7.8	1.3	2.3	0.9	0.0	0.1	9.2	0.9
Vacant	7.1	0.2	2.2	0.4	0.0	0.1	1.7	0.5

Table 3.4: EUI Estimates, Southcentral Regions

Energy Use Index Values (EUIs)

Fairbanks Region

(Kwh/Square Foot/Year)

AVERAGE

Building Type	Heating	Cooling	Vent	Hot Water	Cooking	Refrig	Lighting	Misc
Small Office	9.9	0.5	1.8	1.0	0.0	0.3	9.1	4.3
Large Office	9.9	0.7	5.3	1.0	0.0	0.0	13.3	3.5
Restaurant	10.5	2.1	4.4	7.0	10.7	8.6	7.7	2.2
Large Retail	6.9	1.3	1.7	0.8	0.0	0.1	10.6	2.4
Small Retail	6.9	0.2	1.0	0.8	0.0	1.0	7.4	2.8
Grocery	15.8	1.9	1.6	1.2	1.4	22.4	10.0	5.9
Warehouse	5.9	0.0	0.8	0.8	0.0	2.8	3.1	0.9
Car Service	7.9	0.1	1.7	1.0	0.1	0.1	11.2	3.8
Lodging	9.9	2.8	2.8	3.0	3.0	2.8	8.2	4.5
Medical	16.8	0.6	6.5	2.8	0.3	1.5	10.6	1.1
School	11.5	0.0	2.6	1.8	0.1	0.2	6.0	0.5
College	9.9	4.0	4.2	1.8	0.6	0.5	12.5	1.6
Assembly	9.9	3.0	4.0	1.0	0.8	1.4	10.1	2.5
Miscellaneous	9.9	1.5	2.6	0.9	0.0	0.1	10.6	0.8
Vacant	8.9	0.2	2.5	0.4	0.0	0.1	2.0	0.4

NEW EQUIPMENT

Building Type	Heating	Cooling	Vent	Hot Water	Cooking	Refrig	Lighting	Misc
Small Office	8.6	0.4	1.6	1.0	0.0	0.2	7.9	4.6
Large Office	8.6	0.6	4.6	1.0	0.0	0.0	11.6	3.7
Restaurant	9.1	1.8	3.8	7.0	12.3	7.5	6.7	2.4
Large Retail	6.0	1.1	1.5	0.8	0.0	0.0	9.2	2.5
Small Retail	6.0	0.2	0.9	0.8	0.0	0.9	6.5	3.0
Grocery	13.8	1.6	1.4	1.2	1.6	19.5	8.7	6.4
Warehouse	5.2	0.0	0.7	0.8	0.0	2.4	2.7	1.0
Car Service	6.9	0.1	1.5	1.0	0.1	0.1	9.7	4.2
Lodging	8.6	2.4	2.4	3.0	3.5	2.4	7.1	4.9
Medical	14.6	0.5	5.6	2.8	0.4	1.3	9.2	1.2
School	10.0	0.0	2.2	1.8	0.1	0.2	5.2	0.6
College	8.6	3.4	3.6	1.8	0.7	0.4	10.9	1.6
Assembly	8.6	2.6	3.5	1.0	0.9	1.2	8.8	2.7
Miscellaneous	8.6	1.3	2.3	0.9	0.0	0.1	9.2	0.9
Vacant	7.8	0.2	2.2	0.4	0.0	0.1	1.7	0.5

Table 3.5: EUI Estimates, Fairbanks Region

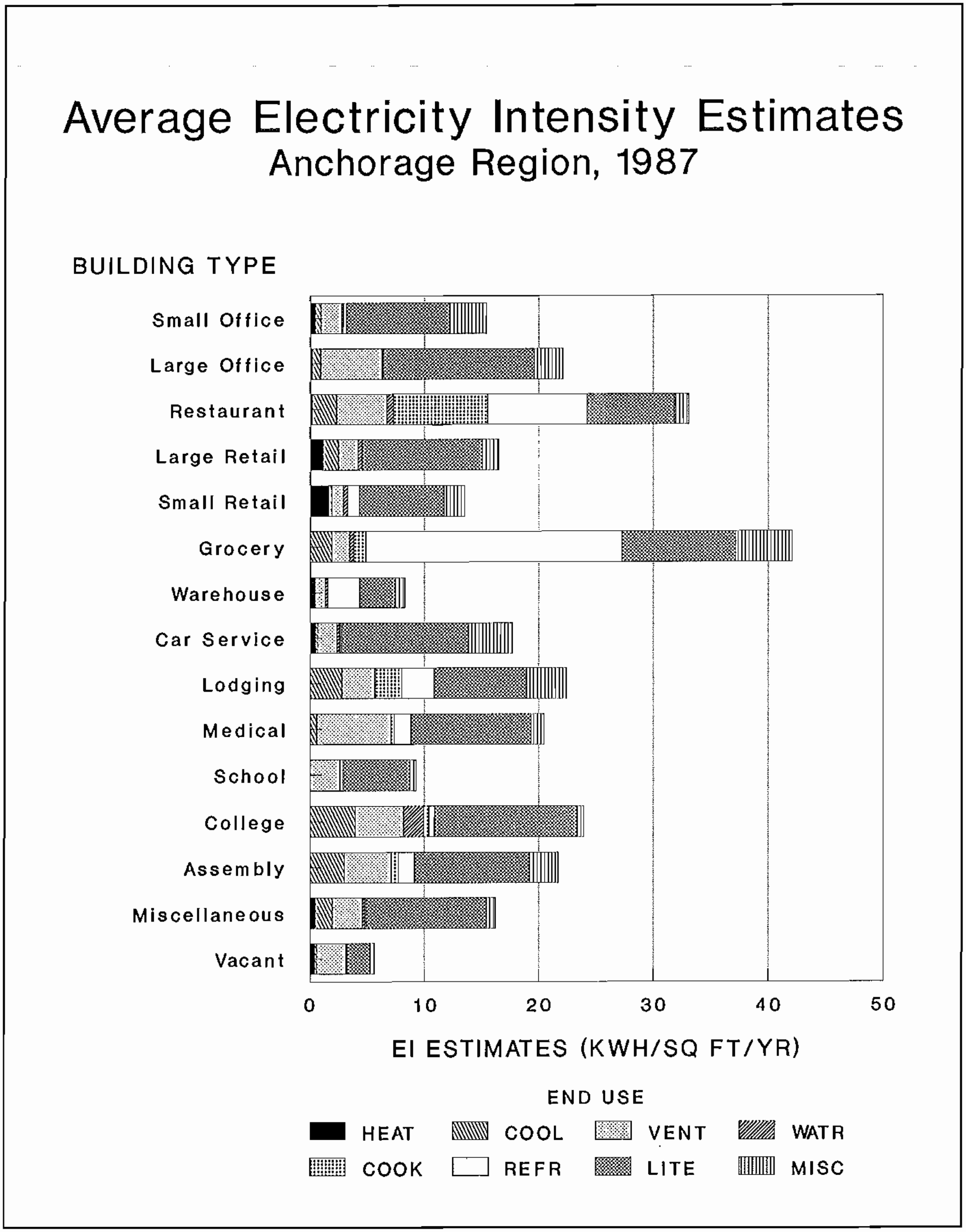

Figure 3.9: 1987 Anchorage Commercial Electric Sales Structure

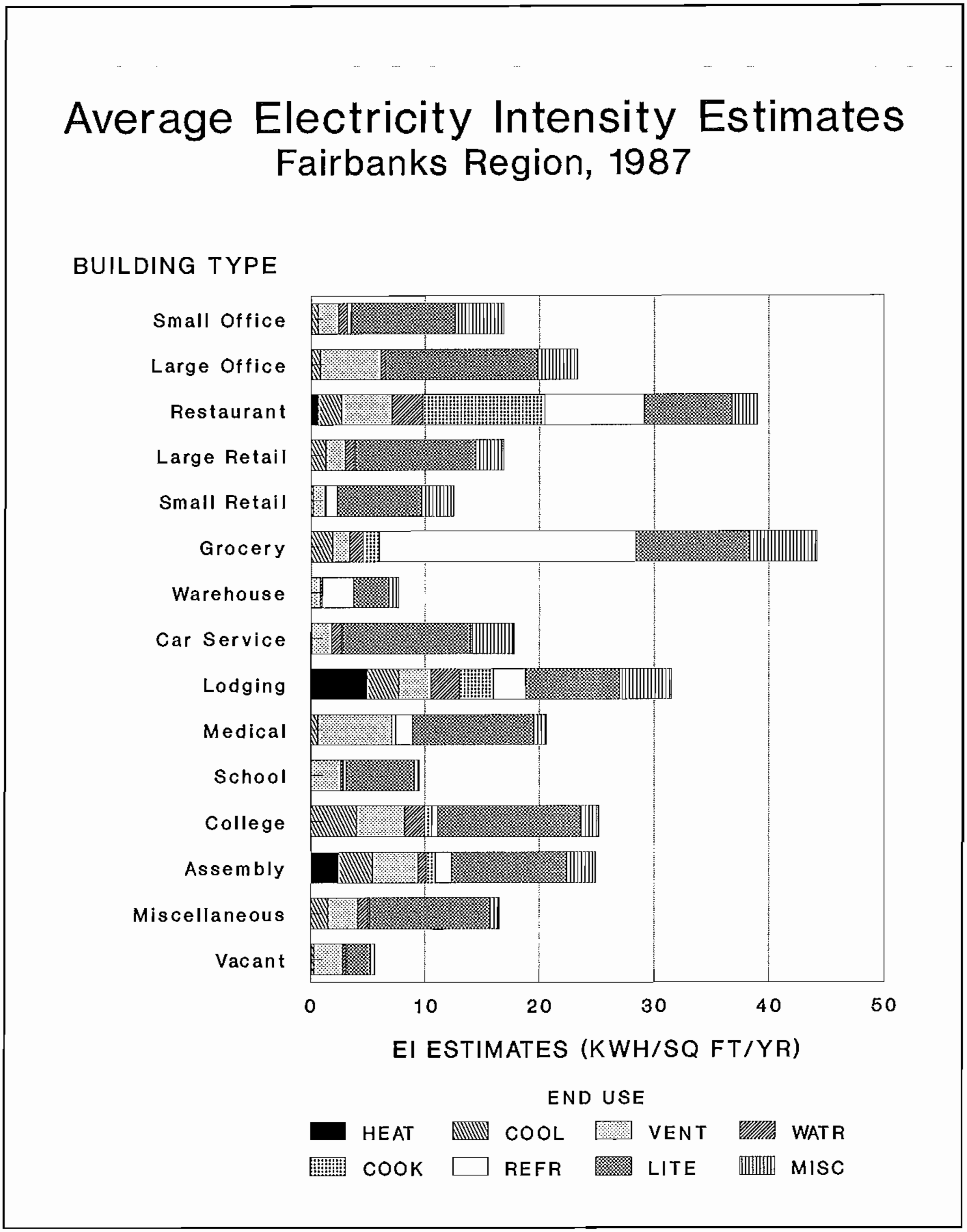

Figure 3.10: 1987 Fairbanks Commercial Electric Sales Structure

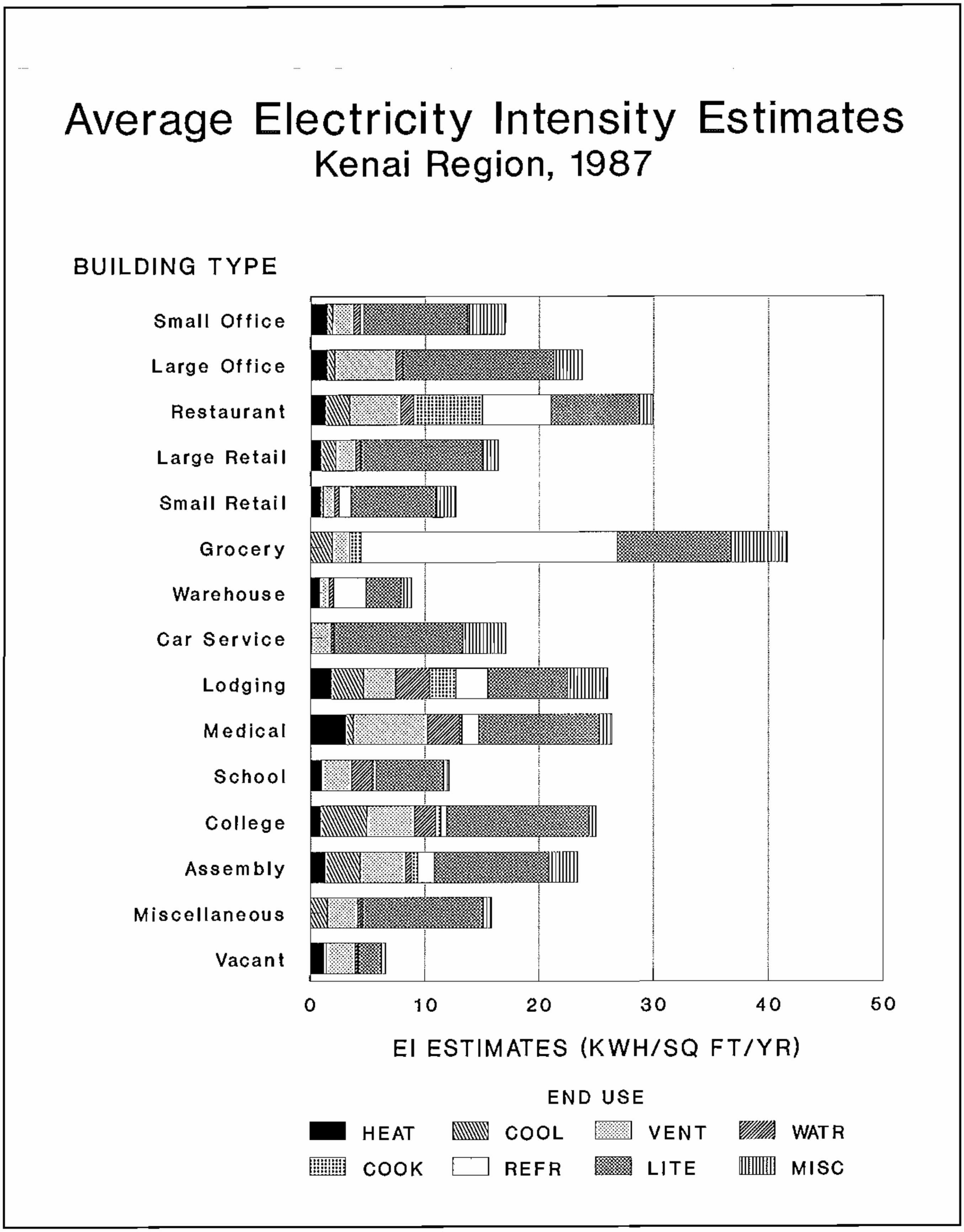

Figure 3.11: 1987 Kenai Commercial Electric Sales Structure

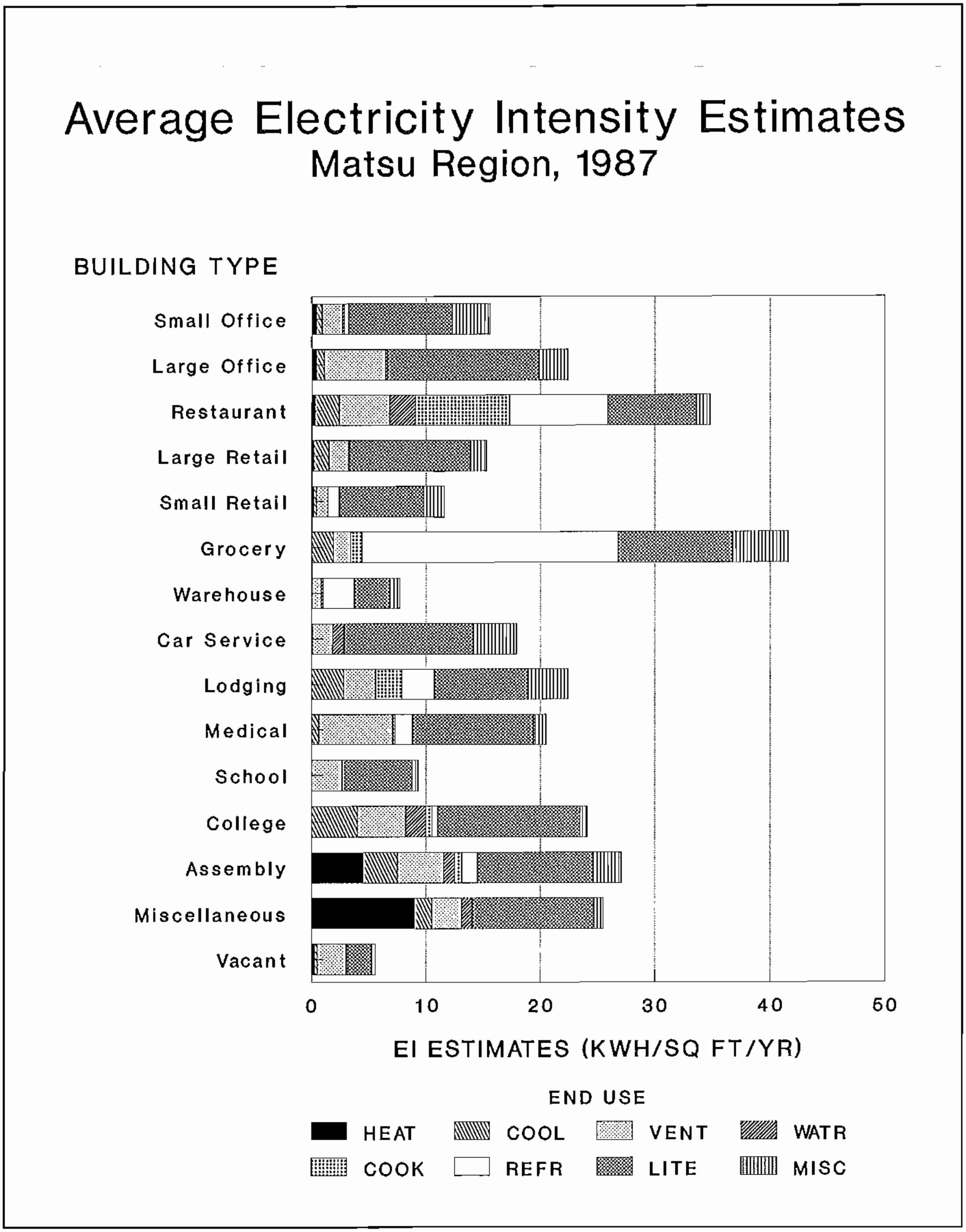

Figure 3.12: 1987 MatSu Commercial Electric Sales Structure